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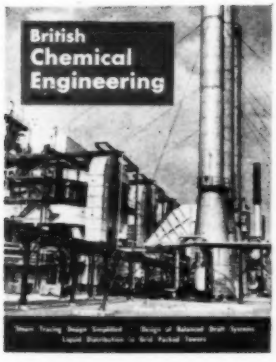

This month's cover illustrates a three-boiler power plant at the Mobil Oil Co. Ltd.'s refinery, Coryton. This employs a balanced-draught system with Lungström preheaters. Each boiler has a capacity of 180,000 *lb./hr.*

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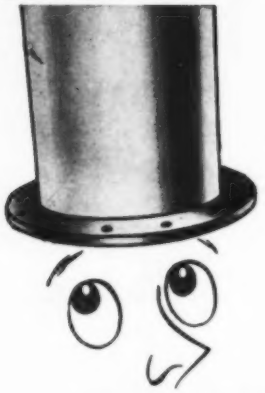

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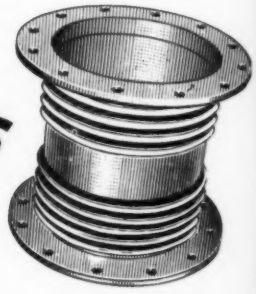

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DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

New I.C.I. Policy on Catalysts

UNTIL quite recently the I.C.I. made catalysts for its own use only. Following the extension and modernisation of its Clitheroe factory, which formerly manufactured catalysts for the Billingham Division, the policy on catalysts has been revised and broadened. Today their sale to undertakings outside the I.C.I. is being energetically pursued. This means that this country now has a greater measure of independence of foreign catalyst supplies than was formerly the case, but the most striking thing about the new policy is the aim to sell not only the catalysts but the processes that go with them. This aim is being undertaken on a world-wide scale without regard to political and economic barriers. For example, a team of experts from the I.C.I. is at present at work behind the Iron Curtain and engaged in negotiations for the sale of the catalysts and processes. Already substantial progress along these lines has been made in Yugoslavia. From America, also, from whom this country originally obtained many of its catalysts, the possibilities for large sales of both catalysts and processes are good and successful sales are in the offing. Sales in foreign countries will strengthen the position of I.C.I. internationally, and will also lead to a valuable exchange of technical experience and ideas.

Making and Welding Titanium

FURTHER advances in titanium technology have been reported since our notes of last month. At Illinois Institute of Technology a new method has been developed for manufacturing titanium, zirconium or other easily oxidised metals of high melting point. Briefly the method consists of reducing the oxide of the metal with an excess of aluminium, to form an aluminium-metal alloy containing some free aluminium. By the use of the excess aluminium excellent separation is obtained between the alloy and the oxides. The alloy has oxygen contents of the order of 0.004%. By leaching with magnesium or magnesium-zinc alloys most of the aluminium is removed from the above alloy until the aluminium content has reached tolerable limits. For titanium this is about 6 to 7 %. Distillation of the residual magnesium and zinc yields a sponge which contains the metal, some aluminium, oxygen below 0.05%, H below 20 p.p.m., N below 0.005%, C below 0.05%. The only contaminants are metals such as Fe and Si, that may have been present in the oxide or the aluminium used for the reduction. Dr. Mondolfo, Director of the Department of Metallurgical Engineering at the Institute has informed us that he was recently granted U.S. Patent No. 2,803,536 covering this process. Welding of titanium has proved to be practicable using a tungsten arc and shielding in an inert gas. At the British Welding Research Association successful techniques have been developed for producing strong titanium-to-titanium joints in an enclosed chamber or employing a nozzle to give the inert gas atmosphere. At the Knolls Atomic Power Laboratory in the U.S., good welds between titanium and hafnium have been obtained by similar methods. The joints were harder and stronger than either metal and alloyed material was present in the weld.

Canned Motors

TO rouse an otherwise equable engineer to helpless fury, mention penetrating or corrosive fluids and pump gland seals in the same breath. The newly developed "canned motors" may therefore serve as technical tranquillisers. In these units the shaft seal between pump and motor has been eliminated by placing both pump and motor in a single pressure-tight housing made in two parts which are bolted together and finally seal welded. With this construction the pumped fluid has access to the motor bearings and normal oil lubrication is impossible. The pumped fluid is the lubricant and good bearing materials which are corrosion resistant in the fluid must be used. The stator is protected from attack by lining its bore with a thin hollow cylinder, usually of a non-magnetic corrosion resisting steel. The rotor is protected in a similar manner. These "cans" are welded leak-tight in position and give rise to the term "Canned Motor". The pumped fluid surrounds the bearings and fills the gap between rotor and stator, so that the rotor friction horsepower is much greater and increases rapidly with speed and diameter.

Because of the thickness of the cans, there is a large "air" gap involving further losses, which reduces the efficiency of the motor below that of a conventional machine. The rotor must, of necessity, be small in diameter and it has therefore a large length-to-diameter ratio. High temperature resisting insulating materials can be used to meet particular temperature conditions. The pump impeller is overhung on the rotor shaft. A heat barrier is fitted between pump and rotor to reduce the transference of heat to the motor. These pumps are likely to have a wide range of uses outside the field of atomic energy for which they were developed.

Studying Gas Dispersions

THE first part of the programme of the new Chemical Engineering Department of the D.S.I.R. Chemical Research Laboratory, Teddington—the elaboration of a method of measuring inter-facial areas in gases dispersed in liquids—has now been virtually completed. The procedure has been applied to a variety of systems with success, and it involves shining a beam of parallel light through the dispersion. Light that strikes bubbles is scattered, but that which meets no obstruction is measured in a blackened tube. Results of the work are to be published early in 1958. The next stage in the programme —the measurement of mass-transfer co-efficients in gas dispersions—is now engaging the attention of Dr. P. H. Calderbank and his staff. The Department's research, which has special reference to fermentation, is still being cramped by lack of space. The whole Department con-

tinues to be housed in only a single room about 20 ft. x 15 ft., and this has to accommodate not only the apparatus, but desks and lathes (for the staff has to do most of its own plant fabrication). Investigations on, for example, conditions in a 6 ft.-diameter tank (instead of at present a 20 in.-diameter vessel) cannot be undertaken as there is no place to put the tank.

New Ion Exchange Resins

In research on ion exchange the C.R.L. has made considerable headway during the past year. The high poylmers group is in the "final stages" of elaborating new membranes for large-scale electrodialysis, and the organic group has synthesised (and demonstrated at the Laboratory's open days recently) a number of new polymers having specific properties. Reducing activity was possessed by new polymers incorporating hydrazine derivatives, and exchange resins having potential uses for removing heavy metals have been made by introducing into the polystyrene molecule arsonic and phosphonic acids. Resins synthesised from the unusual starting material, pyridine, with the use of sodium and carbon dioxide have just been prepared. The inorganic group are soon to start extracting pure rare-earth metals from their compounds separated by ion-exchange techniques. The economics of a method of extracting uranium which makes use of amines as the solvent is being worked out by the radiochemical group, and this group have also evolved a new method for the extraction of thorium from uranium-barren liquors containing as little as 200-250 parts a million of thorium-oxide using an inorganic solvent immiscible with water. The process, it is claimed, can be scaled up easily, but, at present, no information is released on the nature of the solvent.

As part of the Laboratory's programme of compiling, in cooperation with the National Physical Laboratory, accurate information on the thermodynamic properties of compounds the organic group has constructed new apparatus for measuring latent heats of vaporisation and specific heats of vapours. It should help towards attaining the objective of this work—the establishment of a full thermodynamic description of the compounds examined.

Liquefied Natural Gas: Moves by Gas Council

SUGGESTIONS for the importation of liquid natural methane to augment Britain's gas supplies, discussed in *British Chemical Engineering* last month (see Digest page 525) are soon to be implemented, as the first shipload of this cargo will arrive in the Thames estuary within the next eighteen months. This development was announced by Sir Harold Smith, chairman of the Gas Council, at a luncheon in London recently. At the Council's Sales and Service Conference in Harrogate a few days later Sir Harold added that the gas would possibly come from South America, and shipment would start as soon as storage tanks, to be constructed by the North Thames Gas Board, were ready to receive it. Few details are available about the plans as we go to press, but it is understood that the first load will be carried across the Atlantic in a 3,500 ton tanker of special design, with a system of thermally insulated vessels to reduce vaporisation losses to a minimum. Negotiations are under way for constructing two liquid-gas storage tanks each of 1,000 tons capacity at Canvey Island, Essex. The gas would be vaporised there and then piped to Romford Gas Works where it would be diluted and passed into the mains.

Many Sides to Graphite

AS though reacting against the glamour of new materials, workers on carbon have been freshly exploring its properties in great detail. In June the third biennial Carbon Conference was held in Buffalo, U.S.A. In September, a London conference on industrial carbon and graphite (organised by the Society of Chemical Industry) mustered about 70 papers covering such aspects as optical, magnetic and thermal properties, crystal structure, reactivity and electrical behaviour. The final section of the proceedings was concerned with mechanical, chemical and metallurgical applications. Naturally, considerable impetus has been given to this group of studies by the demands of the nuclear energy programmes, but the benefits will extend to more conventional chemical plant applications. An interesting line of thought in using these materials is the development of the block principle, described by A. Hilliard of the *Société le Carbone-Lorraine*. To take advantage of the favourable mechanical properties of graphite and minimise its drawbacks, Mr. Hilliard suggests building equipment from an assembly of carbon blocks composed of easily detachable units. Several practical examples are noted briefly and there is given, in addition, a more extended treatment of a heat exchanger design although this lacks mathematical details.

Self-discipline for Research Chiefs

PUNGENT and pointed were the remarks of Academician A. L. Kursanov* on the self-discipline demanded of the head of a research laboratory. "A laboratory is not a feudal estate awarded as a prize for knowledge achieved but a precious organism entrusted to its head to be fostered"; in saying this Kursanov showed that many problems transcend national peculiarities and forms of society. He added that the ideal head should train independent workers, not be afraid of his pupils, aim to see that they know more than he does and not be embarrassed when they do so. Yet the head himself must not rest on his laurels. He must learn all the time. Like an aeroplane he must keep going to maintain height or climb. For the direct laboratory head stage—as distinct from higher steps up the administrative ladder—is one of the greatest opportunities for creative work. And Kursanov's final *cri du coeur* might well echo in many types of laboratories. "I should like every laboratory head to pause and consider where he needs to close the gap to keep abreast of modern science and lead the young scientists forward, for they will have to go further than their teachers." News of the successful launching of the earth satellite suggests that this type of self criticism can contribute to brilliant achievements.

**Vestnik Akademii Nauk*, 1956, 9.

Vacuum Steel Casting

STUDIES of vacuum steel casting in Czechoslovakia have shown that the only operational method which can be employed is to cast in vacuum and cool under normal atmospheric pressure. It is not practicable to apply vacuum after pouring. Vacuum casting has practical importance only when the residual pressure is less than 40 mm. Hg. In large ingots where vacuum casting gives the greatest profit, considerable improvement of the overall quality can be expected only when pressures of less than 5 mm. Hg will have been achieved. The introduction of vacuum steel casting for large ingots, and later

for large castings will lead to the shortening of production time and a more positive control of the production. The mechanical properties will be more regular, even though, according to present experience, they are not likely to increase much above the maximum values attained for steel produced by the current methods. Details of the work are given in *Hutnické Listy*, 1957, No. 8, 755, in a paper by Eminger and colleagues.

Sugar Inversion During Evaporation

THE dangers of chemical change during evaporation are often discussed in general terms but a recent paper documents the effects for sugar solutions. At Puttershoek sugar factory in the Netherlands it had long been noticed that the colour of the thick juice coming from a "pressure" evaporator was nearly always darker than that from the "vacuum" evaporator. The latter was a quintuple-effect evaporator of 4355 sq. m. heating surface. One of the first bodies was a long tubular one and the others were normal Robert bodies. The heating vapour to the first effect was usually at about 127°C. and that in the other effects respectively 117°, 106°, 97°, 84° and 58°C. The pressure evaporator was of Buckau-Wolf construction with forced circulation. From the second effect vapours were blown off in parallel but the juice passed through it in series. The last effect was a normal Robert body. Heating surface was 4300 sq. m. and the respective temperatures 136°C., 124°, 116°, 105° and 90°. The criteria used in the investigation were the change in *p*H, determinations of invert sugar and measurements of the colour with a colorimeter. Results presented by P. C. Loopuyt—who has unfortunately since died—showed that the pressure evaporation resulted in decomposition of more sucrose than the vacuum evaporation. The author therefore concludes that if the purchase of a new evaporator is being considered it should be realised that the same vapour economy can be obtained with a so-called vacuum evaporator as with a pressure evaporator although the former is more expensive.

P.C. Loopuyt, *International Sugar Journal*, 1957, 59, 243.

Desalting Mine Water on a Large Scale

RESULTS of pilot plant work on electrodialysis of mine water in the Orange Free State have shown that a large-scale plant is an economic possibility. The estimated maximum cost of treating the water including provision for interest and redeeming capital is 2s. 6d. per thousand gallons. The plant is planned to treat 3 million gallons a day of saline water containing 4000 p.p.m. of salts. It should yield 2.4 million gallons a day of water containing 1000 p.p.m. of salts. Water of 3000 p.p.m. can be purified to 500 p.p.m. which complies with the South African Bureau of Standards' requirements for domestic water supplies. The story of the development of this project has recently been told by W. H. Moyers in *Optima* (1957, 7, 135). The plant—consisting of a pre-treatment unit and an electrodialysis unit proper—is expected to be commissioned in 1958. Experience gained here can be of great value in many other parts of the world where development is held back for lack of suitable water supplies though large quantities of saline waters are available.

Working up the Fission Products

TURNING a nuisance waste into a useful product has always been an attractive theme to the chemical industry. It was therefore interesting to see papers on recovering individual fission products from the residual solutions after extraction of plutonium which were presented at the UNESCO Conference in Paris on radio-isotopes. The mixed fission products produced as a by-product of atomic energy programmes provide a potential source of radio-isotopes which far exceeds all likely demands. The removal of specific isotopes for industrial use also reduces the problem of dealing with the wastes. The separations however are very difficult because the mixtures are so complex. Nevertheless, the industrial group of the Atomic Energy Authority state that they have developed methods for producing from this material intense sources (1000-2000 curies) of caesium 137 and smaller sources of unusual isotopes such as neptunium 137. The importance of the separation of caesium 137 was emphasised by a paper from the French Atomic Energy Commission pointing out the change with time of the radio-active composition of the products from the reactors at Marcoule. This isotope represents 30% of the gamma energy of the fission products on leaving the plutonium factory, 70% two years later and practically 100% at the end of five years. It is thus much more useful than the crude mixture. One possible field of application was discussed at the symposium on irradiated foods held at Cambridge recently, although the conclusion was that food preserved by radiations is not likely to be seen in the shops for some years.

Determining Oxygen Continuously

OXYGEN in flowing gases can be determined continuously with great ease and with a sensitivity so far unattainable by any other means by using systems of the type gas/partly immersed cathode/electrolyte/base metal anode. Without amplification, a full-scale deflection can be obtained for one volume oxygen per million and even small concentrations. For higher concentrations simple dilution techniques can be applied and ranges up to several per cent. can be covered. A rapid, linear response can be obtained, the blank is negligible and no auxiliary gases are required for calibration. Oxygen in liquids such as high-presssure boiler feed water can be recorded with the aid of a scrubbing carrier gas. The instrument has been variously used in England for industrial as well as research purposes. Design and applications are discussed by P. Hersch* who recommends the system gas/partly immersed silver/caustic potash solution/lead as the most suitable combination. One so-called "dry" cell development of this type produces some 6μA for each volume oxygen per million in a stream of 100 c.c. of gas per minute. For concentrations of the order of a few per cent. an instrument based on the "magnetic wind" principle may be used without dilution of the gas. This depends on measuring the paramagnetism of oxygen. The method has recently been re-discussed in the course of an article by Farquhar† on applying analysis for residual oxygen to combustion control. It was also described by E. H. Coleman, *British Chemical Engineering*, 1957, 2, 205.

* Hersch, P., *Instrument Practice*, 1957, 11, 817.
† Farquhar, J.C., *Instrument Engineer*, 1957, October, 65.

Gas Leakage from Welding Torches

IN a recent accident an explosion in a vessel 16 ft. by 16 in. diameter shattered a welder's hand and caused him to fall to his death. The explosive mixture was produced by seepage of propane from a welding torch that had been left on top of a job in the fresh air overnight. The main supply of propane had been turned off after work finished but not before enough had leaked through the torch or its connections into the enclosed space and formed the

explosive mixture. It is well known that welding torches should not be left in obviously confined spaces overnight. It is now evident that there is danger in leaving them in more open surroundings, if there is an enclosure nearby where gas can accumulate. Reporting this fatality, *Accidents*, 1957, Vol. 32, the organ of the Factory Inspectorate, recommends that torch hoses should be disconnected at the supply bottles whenever the torch is taken out of use for other than a short period. Merely turning off the valves at the bottles has been shown, by accidents that have happened, to be inadequate.

Perspectives

ENGINEERS are liable to immerse themselves in their design and development work—scorning alike the "politicians" on one wing and the "pure scientists" on the other. The former tend to ask why a project was started and what good or bad it will do; the latter ask why certain engineering conventions have arisen and what are the fundamental mechanisms of processes. Healthy correctives to technical narrow-mindedness have now been provided on both wings. Professor Blackett at the British Association Dublin meeting this year set out to document his thesis that more stress should be laid on the social consequences of modern science and technology. On the other wing Dr. Libby of the U.S. Atomic Energy Commission re-stated the case which we have at the back of our minds but sometimes leave there. In principle "being in favour of basic research is somewhat like being against sin: it is nearly unanimous." In practice it must be sharply distinguished from development work and funds earmarked for research which is intended specifically and simply to tell us something new about nature.

Rational Construction

TO say that equipment should be constructed on a rational basis could be an empty truism but W. Rodenacker has recently developed this theme with practical examples. The author paraphrases the term "rational construction" as meaning working according to scientific principles. The question is then to decide what are the starting elements of a process and which way can lead to an optimum solution. Hitherto, points out Dr. Rodenacker, it has been usual in process work to start from the plant suppliers or the standard established pieces of plant or machines and suit them to the needs of the job. But the optimum solution of a problem may be quite different from that obtained by using existing machines. The author's method of filling out this concept is difficult to summarise usefully and we would refer our readers to the original article* which includes an application to developing a new mixing machine for viscous solutions.

* Rodenacker, W., *Chemie-Ingenieur-Technik*, 1957, 29, No. 9, 573.

How Much Research?

WHEN the U.S. Department of Labour carried out a survey of science and engineering in that country in 1953-4 they found that more than half of research budgets "are determined by purely judgmental appraisals of company needs and resources." A mathematical model to provide a basis for such judgment has now been put forward by D. Dresden. His argument is divided into two parts. First he asks what is the relationship between the final (maximum) value of the annual returns and the initial expenditure to achieve a balance. This is followed by considering what percentage of extra advantage, as profits on the annual sales, a firm can maintain over its competitors who of course will themselves be fighting back. A curve and its equation are presented to show how revenues accrue in the course of a number of years. Allowance is made for the losses involved in discarding unpromising lines. The tightly reasoned argument leads to formulae which allow for interest rate on capital, the extra profit which it is assessed can be maintained by the research programme, and also the length of cycle after which the research results will be superseded. Modestly disclaiming the formulation of a "law," Prof. Dresden considers that his argument may give an insight into the factors determining the percentage of the turnover that can profitably be invested in research and development. A further branch of this work can be applied to determine the expenditure justified when considered in terms of national or world economy.

Dresden D. *Research*, 1957, 10, No. 7, 261.

Linking Pumped Storage and Nuclear Power

SINCE nuclear power stations have high capital costs and low running costs it is desirable to run them continuously. If nuclear capacity of 6000 MW is commissioned by 1965 over one quarter of Britain's electricity requirements will be met from nuclear stations. Unfortunately only about 15% of electricity load in the U.K. is continuous. This gives added urgency to the plans for pumped storage of water which has long been discussed in general terms and is at present the only commercially practicable way of storing electric power on a large scale. Sir Donald Perrott, K.B.E. (the Finance Member of the Atomic Energy Authority) recently reviewed the pumped storage schemes which are at present under consideration. Sir Donald understood that the prospect of coupling the Blaenau Ffestiniog pumped storage plant to a nuclear power station is being considered and pointed out that suitable sites for similar schemes are plentiful in the Scottish Highlands. A small pumped storage scheme has been commissioned in Argyllshire and the Awe Project provides for the construction at Cruachan of an even larger scheme than that at Blaenau Ffestiniog. Its capacity will be some 400 MW.

Bricks from Fly Ash

THERE is nothing new in adding coal ashes to clay in brickmaking. The practice goes back at least to the eighteenth century in south-east England. Yet we understand that modern brickmakers consider the making of bricks from fly ash—the fine ash from pulverised fuel—to be a menace and it seems that the Central Electricity Authority has been virtually forced into considering making its own bricks. Building Research Station has now presented a series of papers on this subject and Mr. Batley, Midlands Divisional Controller of the C.E.A., informs us that his Division is hoping to build a pilot plant based on this work. Though the brickmaker may not be interested in p.f. ash as a raw material, the generation engineer is very interested in bricks as a possible outlet for the p.f. ash—currently running at about 3 million tons per year. Brickmaking represents a very great potential use. The annual output of bricks is of the order of 20 million tons and satisfactory bricks can be made with 80% ash, 20% clay. But there are at least three other fairly firm and incipiently large-scale uses for the fly ash. It can be made to yield light weight aggregate or be formed into other building materials and can be used to recover waste land to agriculture.

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Automation and Engineers

IF the first industrial revolution could be looked upon as a revolution in power—the replacing of man's physical efforts by the motion and machinery—then the second industrial revolution, through which we are now passing, bids fair to become one of communication—the substitution of man's more tedious mental efforts and control actions by automatic machinery.

How these developments have made their impact upon engineering practice is shown by the number of important conventions held by professional bodies in this country over the past year or two. These conferences have helped engineers in many fields of industry to recognise the benefits of the various computational and automatic control techniques, which are the main ingredients of automation, not only to perceive the advantages of the new methods but also to distinguish their pitfalls.

The efforts of the Institution of Electrical Engineers and the Society of Instrument Technology last year in this direction are especially noteworthy. Whereas the former body devoted its conference to the digital computer, the latter dealt with the influence of the behaviour of the process and plant to be controlled upon the control system. Although the value of the computer conference was undeniable, it was perhaps unfortunate that no papers by or for chemical engineers were presented to demonstrate the remarkable usefulness of computers in their field. For such was the burden of interpretation left by this meeting that its usefulness remained in obscurity for most chemical engineers. But this, as we shall see later, need not arise in the future. A great deal can be said of the role of computers in a number of fields and of the problems they can help to solve. Fundamental research, design and the evaluation of process operations are some of the areas which are becoming increasingly influenced by computer practice. In the long run they will become the prime component of many automatic control systems. The ability of the electronic digital type of computer to simulate the behaviour of physical systems is, for example, an immensely valuable property to the designer. Distillation equipment, to mention one of the forms of plant most familiar to the chemical engineer, provides a useful field for exploiting this property, for not only can the large number of heat and material balance calculations required to produce a design be carried through rapidly, but the design itself can be tested for a variety of operating conditions and the effects of disturbances upon operation can be elucidated without recourse to an actual plant. Where variables depending upon chance enter into the reckoning is another field where the computer is immensely useful.

The meeting held by the Society of Instrument Technology in Cambridge last year was much closer to the ground and of much more practical interest to the chemical engineer. This perhaps is not surprising, since the purpose of the meeting was to bring together research workers in the field of measurement and control and the men engaged in the design and use of control equipment. The subject of the conference was a highly important aspect of automatic control, namely, the influence of the process and plant behaviour upon the control system, and the practical nature of the papers presented can be judged from a scope which embraced continuous multi-component distillation at one extreme to batchwise heating in jacketed kettles at the other. Both papers and discussions were heavily weighted in the direction of chemical engineering and most of the material presented was concerned to establish the facts about existing plants and processes. The prediction of the characteristics of plant at the design stage, and the working out of new methods of plant design and control systems in order to give greater efficiency and superior product quality, were subjects left over for further development.

In view of the host of advances which are continually being made and the difficulty the practising engineer has to keep pace with the latest developments and to discern in them what is useful to him, the recent formation of the British Conference on Automation and Computation is a welcome step. This conference arose from a study by a number of professional bodies of the relationship of these two subjects to their respective branches of engineering, as well as the problems of interpretation and application which face their respective membership.

This new organisation is to be divided into three main groupings. The first to deal with the engineering applications, the second with computers, automatic control and programming techniques, while the social and economic consequences of these two techniques will be studied by the third group. Finally, the activities of these three sections will be co-ordinated by a liaison committee.

The aims which this conference has set before itself are to separate, classify and rationalise the material coming to it from a number of sources. When the work is well under way the practising engineer will find it very much easier to know what is going on in these two fields to avoid unnecessary searching and to recognise what is useful.

We can expect this conference to play an important part in bringing about improved working between the various kinds of engineer and the computer and instrumentation experts. The eventual outcome of this will be better equipment and greater productivity at less cost.

Today, with automatic process computers and the other ingredients of automation able to perform millions of calculations and control actions with a speed and reliability far beyond the capabilities of human beings, the automatic factory is in the offing. This goal will be reached and applied where economically feasible, and much sooner if the new body can fulfil its mission. Last, but not least, this country can now be properly represented at international conferences devoted to automation and computers.

DESIGNING NATURAL- AND BALANCED-DRAUGHT SYSTEMS

by S. J. MICHELL, M.Sc., A.M.I.Chem.E.

The theory of the chimney effect is described and the design aspects of natural and balanced exhaust systems are briefly discussed. These are supported by a worked example

IN the design of a draught system attention is usually focused upon the mechanical means of creating draught. For small resistances to flow, however, the chimney may be a very economical and more satisfactory means of moving gases than a power-driven fan. The reliability and extremely low maintenance cost of a chimney may well outweigh the high initial investment it represents. And even though the total resistance in a draught system exceeds that which a chimney is able to overcome, the latter is still worth considering in conjunction with other conventional means of producing draught. Moreover, when the designer is faced with a serious disposal problem he may be obliged to include a chimney in his scheme. In some branches of the chemical industry, for example, chimneys as high as 350 to 600 ft have been used[1] to dissipate noxious fumes to the surrounding atmosphere with the minimum of nuisance. Quite tall chimneys are in common use in roasting and sintering processes and, under very much different conditions, with natural draught cooling towers. This article is concerned mainly with the theoretical aspects of chimney design and with the type of system where an additional means of producing draught has to be provided in addition to the chimney. Such a system, where the fan is placed at the inlet of the installation, is known as a balanced-draught system.

Theoretical Considerations

The draught produced by a chimney depends on its height, the temperature of the gases flowing through it, and the conditions of the external air. For a given height, the theoretical draught (i.e., one without losses) is equal to the density difference between the surrounding atmospheric air and that of the hot chimney gases; since the latter vary considerably in temperature with the height, a mean density based on the mean temperature inside the chimney is used. The actual, or the net draught, produced by the chimney is obtained from the theoretical draught by deducting from it the energy losses due to friction and due to the velocity head in the chimney.

Symbols

D = chimney diameter (ft);
d_p = pressure drop in Fanning equation (lb./sq. ft);
g = gravity acceleration (32.2 ft/sec.^{2});
G sec. = mass-transfer rate (lb./sec. sq. ft);
G_t = mass-transfer rate (lb./hr sq. ft);
H = chimney, height (ft);
h_c = pressure drop in chimney (in. H_2O);
$M_{av.}$ = average molecular weight of flue gases;
P = factor (dimensionless);
ρ = density (lb./cu. ft);
t = temperature (°F);
T = absolute temperature (°R);
u = flue gas, mean velocity in chimney (ft/sec.);
a, f, g, g' = subscripts, referring to air, fire-box gas, flue gas (mean value) and flue gas (chimney base level) respectively; and
$\triangle, \triangle'$ = change in draught produced by altering system.

Draught Equation

Referring to Fig. 1, the chimney effect can be visualised by considering the column of the cold air (bounded by dotted lines) identical in height and volume with the column of the hot gases in the chimney. The difference in weight between the two columns is the measure of the draught performance.

The following draught equation is obtained by the application of Bernoulli's theorem between the air entrance and the hot gas exit:

$$H(\rho_a - \rho_g) = \left(\frac{u^2}{2g} + F\right).\ \rho_g \qquad \ldots.(1)$$

in which H is the chimney height (ft), ρ_a and ρ_g the air and the hot gas densities, respectively (lb. cu. ft), u, the hot gas linear velocity based on its mean density (ft/sec.), g, the acceleration due to gravity (32.2 ft/sec.^{2}), while the

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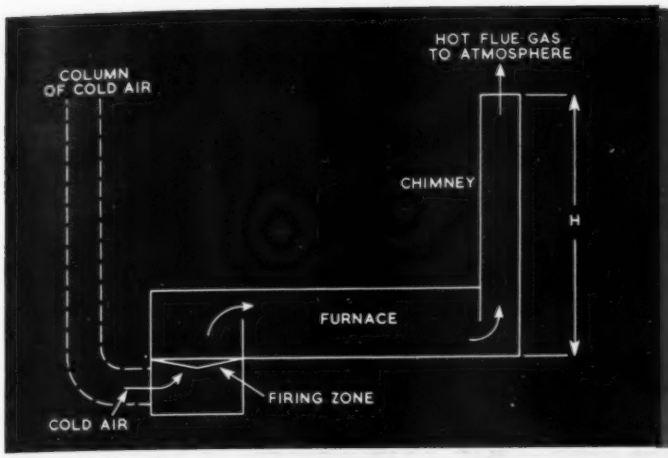


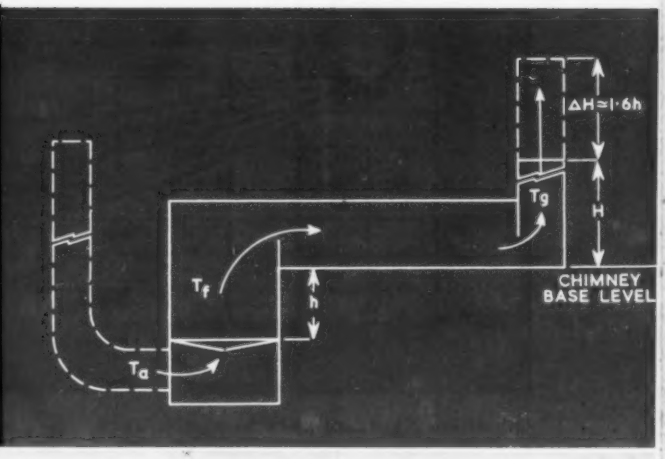


Fig. 1 (left). Diagram showing the principle of the chimney effect. Fig. 2. Diagram to show the effect of altering the position of the firing zone. Decrease in height by h *is equivalent to increasing the chimney height by 1.6*h *approx.*

term F includes all the frictional losses within the system selected in feet units.

It will be noted that both sides of the equation are expressed in pressure units (lb./sq. ft).

Optimum Operating Conditions

In the following treatment it will be observed that, other things being equal, the performance of a chimney is determined by the temperature of the hot gases.

Replacement in the equation of the linear velocity by mass rate, $u = G$ sec./ρ_g (where G sec. is expressed in lb./sq. ft sec.), and the frictional term by $F = K \cdot u^2/2g$ (in which K is a constant) transforms the equation to:

$$H(\rho_a - \rho_g) = (1 + K) \cdot \frac{G^2 \text{ sec.}}{2g \cdot \rho_g} \qquad \ldots.(2)$$

Solution for G sec. leads to:

$$G \text{ sec.} = \sqrt{\frac{2g\,H}{(1+K)}} \cdot \sqrt{(\rho_a - \rho_g)\,\rho_g} \qquad \ldots.(3)$$

Differentiation against ρ_g gives:

$$\frac{d\,G\text{sec.}}{d\,\rho_g} = \tfrac{1}{2} \cdot \sqrt{\frac{2g\,H}{(1+K)}} \cdot \frac{(\rho_a - 2\rho_g)}{\sqrt{(\rho_a - \rho_g)\,\rho_g}} \qquad \ldots.(4)$$

Equating to zero for a maximum provides us with the following answer for (G sec.) max.: $\rho_a = 2\,\rho_g$.

This relation states simply that the best performance of a chimney (i.e., its maximum capacity) is when the mean density of the hot gases is half of the density of the surrounding air.

Assuming the ideal gas law and disregarding the small variations in pressure, the optimum operating condition for a chimney is when

$$T_g = 2T_a \qquad \ldots.(5)$$

in which T_a and T_g are the absolute temperatures of the atmospheric air and the chimney gas, respectively. From this we conclude, assuming 70°F for air ($T_a = 530°R$), that the optimum operating temperature inside the chimney should be 600°F ($T_g = 1060°R$).

Effect of Location of Firing Zone

Referring to Fig. 2, it is assumed that the firing zone (and so the air inlet plane) has been moved farther down from the chimney base by the distance of h feet.

Since the left-hand side of Equation (1) relates the draught magnitude to the density difference between any two sections of the gas stream, the additional draught produced by the change is given by:

$$\triangle = h\,(\rho_a - \rho_f) \qquad \ldots.(6)$$

where ρ_f is the density of the hot gas at the chimney base leve (i.e., the air inlet plane in Fig. 1).

The working temperature of most furnaces is well above 2000°F. Assuming it to be equal to $T_f = 5 \times 530°R$, and taking again for air $T_a = 530°R$, the additional draught under optimum operating condition ($\rho_a = 2\rho_g$) is foun from Equation (6) by substitution for $\rho_f = \frac{\rho_a}{5} = \frac{2\,\rho_g}{5}$ (since $T_f = 5\,T_a$), to be:

$$\triangle = h\,(2\,\rho_g - \tfrac{2}{5}\,\rho_g) = \tfrac{8}{5}\,h\,\rho_g.$$

It may be observed that the addition of h feet to the chimney height will produce only:

$$\triangle' = h\,(\rho_a - \rho_g) = h\,(2\,\rho_g - \rho_g) = h\,\rho_g.$$

This can be exemplified by assuming the firing zone to be moved down from the chimney base by 10 ft. The additional draught thus produced would be compensated by a 16-ft increase in the chimney's height.

Design Factors

The three main factors which have to be considered in designing a natural-draught system are the economic velocity of the hot gases, the heat losses and the pressure drop. The first quantity will determine the cross-section of the chimney, the second the mean temperature of the hot gases, and the last the net chimney effect and hence its height. The establishment of the design values of these three factors is largely based on empirical correlations.

Economic Velocity

There is no degree of standardisation of gas velocity in chimney design. The approach is based, as it might be expected from the general practice in fluid flow, on economic grounds. The only departure from the latter may be due to the air leakage which, in some brick instal-

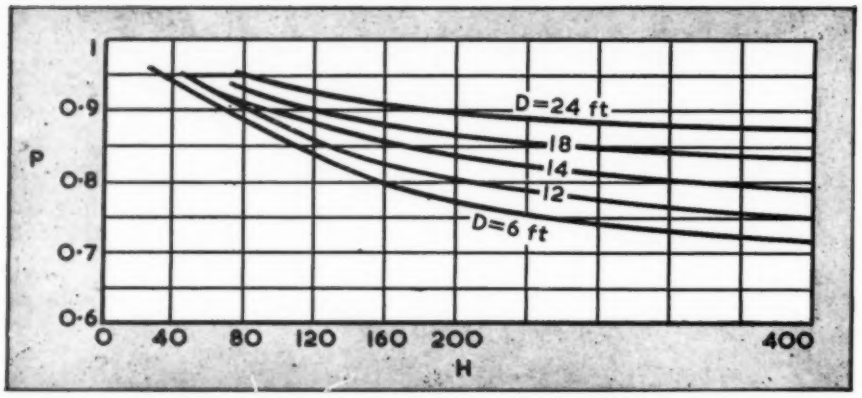


Fig. 3. Plot of factor P vs. H chimney height, with chimney diameter as parameters.[4]

lations, may increase the rate of flow of the hot gas by even as much as 20%.[2] To allow for such an additional burden, and also for the extra cooling effect, up to 10% of the area should be added. Tables of economic chimney proportions against its capacity may be found in handbooks. On the economic velocity basis, Williams[2] quotes the following design figures.

Capacity, cu. ft/sec.	Economic velocity, ft/sec.
10	10
50	15
150	20

There is a gradual increase in velocity with higher capacities, but 30 ft/sec. may be regarded as a practical limit. Many sources indicate that this limiting velocity may be applied to capacities around 500 cu.ft/sec. and over. Once fixed, the velocity will determine the cross-section of the chimney (and also the pressure drop). For small plants, for which steel stacks may be used, the minimum cross-sectional area should not be less than 64 sq. in.[3] Due to bricklaying difficulties, the minimum inside diameter of brick chimneys must not be less than 27 in. and the smallest size usually built is 30-36 in.

Mean Temperature

The mean temperature of flue gases has been defined as the temperature existing midway between the base and the top of the chimney. Since the drop in temperature is due to heat losses through the chimney's wall, and, to some extent, to the unavoidable air leak, its estimation is an approximation. As a first approximation, 0.5 to 1.0°F drop may be assumed for each foot of the chimney height. The two limits refer to brick and thinly lined steel, as constructional materials, respectively.

For brick constructions only, Cotton[4] presents the following equation:

$$t_g = (t_g' - t_a) \times P + t_a \qquad \ldots.(7)$$

in which t_a and t_g' are the respective temperatures of air and flue gas at the base of the chimney, t_g is the unknown mean temperature, while P is a factor obtained from Fig. 3.

For most practical cases, the equation may be reduced to the form

$$t_g = P \,.\, t_g' \qquad \ldots.(8)$$

without introducing much error in calculation.

Pressure Drop

The term (F) in Equation (1) represents the sum of frictional losses encountered in the system between the air inlet and the flue gas exit. (The equation applies to natural-draught systems only.) Some of the losses may be evaluated from the Fanning equation or its modifications. For non-isothermal flow, the Sieder and Tate[5] correlation is of particular value.

Referring to chimney losses only, several empirical formulæ have been suggested. One, which seems to be most convincing, has been developed by Reber[6] to the following form:

$$h_c = (1 + 0.09\ H/D) \,.\, \frac{u^2\ \rho_g}{2\ g} \cdot \frac{1}{5.2} \qquad \ldots.(9)$$

where h_c is the loss in the chimney, expressed in inches of water, H/D is the ratio of the chimney height to its diameter, u and ρ_g are the velocity and the density of the flue gas determined at its mean temperature, and g is the acceleration due to gravity.

Losses through packing materials, such as wooden grids in cooling towers, are best determined by means of the velocity head method, the data for which are readily available.

Many other losses, which cannot be calculated from formulæ, have to be approximated and based on experiment and judgment. Thus, for example, unobstructed fireboxes and process units will offer negligible resistance; on the other hand, obstructions of any form, such as baffling arrangements, economisers, preheaters, etc., may add several inches of water to the overall pressure drop.

Balanced-draught Systems

Chimneys are practically limited to draughts of just over 2 in. of water, on economic basis, the corresponding height being approximately 250 ft. The draught requirements above this limit compel the use of mechanically-operated equipment, i.e., fans and blowers. (The use of steam-jets is confined to the smallest installations only, e.g., locomotive boilers.)

Chimneys, fans or blowers may be employed separately or in combination. The most favoured combination comprises a forced-draught unit (blower), together with a natural-draught (chimney) or an induced-draught (fan) installation. The system so created is known as a "balanced-draught system". Its main advantage lies in the fact that the furnace pressure may be maintained at a slightly negative value, thus preventing the flame escaping through the fire-doors or hot gases leaking outwards through the brickwork.

Illustrative Example

Problem. Specification of the draught system is required for a wet-process rotary cement kiln. The kiln is of 11 ft diameter and 250 ft long. The integral clinker cooler, which also acts as an air preheater, adds another 100 ft to the length.

Data and Assumption

Slurry feed, rate ... ... 45,000 lb./hr

Fuel gas (CH_4) rate ... ... 23 cu. ft/sec. at 15.2 psia, 60°F

Slurry composition ... ... $H_2O = 44\%$
Solid mix. $= 56\%$
The solid mix. contains ... ... 33.9% CO_2
(in the form of carbonates)
20% combustion air and no clinker losses are assumed.

Heat balances indicate that the flue gases will leave the kiln at 800°F. It is proposed to recover some of the heat by cooling the gases to 650°F in a waste heat boiler. The general plant arrangement is represented diagrammatically in Fig. 4.

Solution

Material balances: 1 sec. basis.

Slurry	% by wt.	lb./hr	lb./sec.	lb. mole/sec.
H_2O =	44	20,000	5.56	0.3085
Solids =	56	25,500	7.08	
Total =	100	45,500	12.64	
CO_2 to flue gases = 7.08×0.339 =			2.40	0.0545
Clinker product =			4.68	

Fuel gas rate: $\dfrac{23 \times 492 \times 15.2}{359 \times 520 \times 14.7} = 0.0625$ lb. mole/sec.

$\equiv 1$ lb./sec.

Combustion reaction: $CH_4 + 2O_2 = CO_2 + 2H_2O$.

Air requirement

	lb. mole/sec.	lb./sec.
Theoretical O_2 ... ... =	0.1250	4.80
20% excess ... ... =	0.0250	
Total $N_2 = 0.15 \times \frac{79}{21}$ ... =	0.5640	15.80
Total air ... ... =	0.7140	20.60

Flue gases, rate and composition

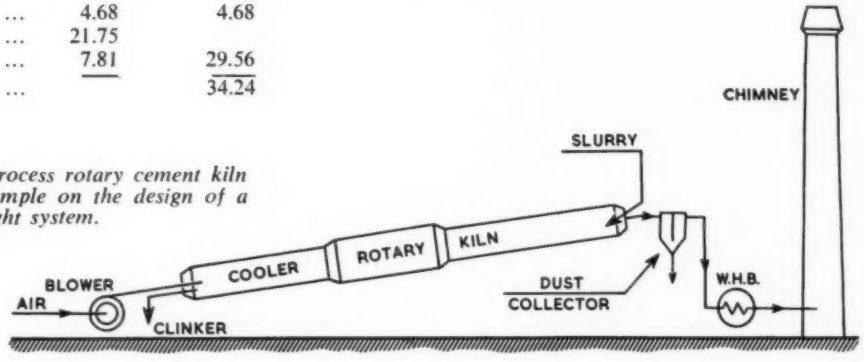
	lb. mole/sec.	lb. mole/sec.	lb./sec.	% by vol
CO_2 from combustion =	0.0625			
from solid mix =	0.0545	0.1170	5.15	10.2
O_2 excess ... ... =	0.0250	0.0250	0.80	2.2
N_2 ... ... =	0.5640	0.5640	15.80	49.5
H_2O from combustion =	0.1250			
from slurry =	0.3085	0.4335	7.81	38.1
Total ... ... =		1.1395	29.56	100.0

Average molecular weight, $M_{av.} = \dfrac{29.56}{1.1395} = 26$

Summary: Kiln material balance, lb./sec. basis.

	Items	Totals
Materials in:		
Slurry feed		
H_2O	5.56	
Solid mix	7.08	12.64
Fuel gas	1.00	1.00
Air	20.60	20.60
Total materials in		34.24
Materials out:		
Clinker	4.68	4.68
Dry flue gas	21.75	
Water vapour	7.81	29.56
Total materials out		34.24

Fig. 4. A diagram of a wet-process rotary cement kiln illustrating the numerical example on the design of a balanced-draught system.



WASTE HEAT BOILER

Duty: To generate 100 psi steam by cooling $29.56 \times 3600 = 106{,}500$ lb./hr flue gas from 800°F to 650°F. (Specific heat of the gas at the mean temperature of 725°F is 0.27 Btu/lb. °F.)

Heat load: 106,500 (800-650) $\times$ 0.27 = 4,300,000 Btu/hr.

Type: fire-tube, horizontal.

A rough estimation indicates that the requirement will be met by an arrangement of 400 steel tubes, of 3 in. nominal diameter (Schedule No. 80) and 10 ft long.

The following is a concise check on performance.

Tubing dimensions:

Inside diameter ... ... = 2.90 in.
Flow area ... ... = 0.0459 sq. ft
Inside surface per unit length ... = 0.760 sq. ft/ft

Mass velocity, hourly basis:

$$G_t = \frac{106.500}{400 \times 0.0459} = 5800 \text{ lb./hr sq. ft.}$$

The allowable mass velocity is from 5000 to 10,000 lb./hr sq. ft.[7] Then from this standpoint the arrangement is satisfactory.

Overall coefficient

For 100 psi steam, the temperature outside the tubes is 328°F.

$$LMTD = \frac{(800 - 328) - (650 - 328)}{2.3 \log\left(\dfrac{800 - 328}{650 - 328}\right)} = 392°\text{F.}$$

The overall heat-transfer coefficient based on inside area, is then:

$$U_i = \frac{4{,}300{,}000}{(392)\ (400)\ (10)\ (0.76)} = 3.6 \text{ Btu/hr sq. ft °F.}$$

For fire-tube economisers the heat-transfer rates are approximated by $U = 2.0 + 0.0015\ G_t$ for clean surfaces.[7] On this basis only, the coefficient would be $U = 10.7$ Btu/hr sq. ft. The selected size therefore makes a good allowance for the departure from non-boiling conditions and for a rather large dirt factor.

Pressure drop

Using the Fanning equation with entrance and exit losses, the drop in pressure, in psf units, is given by:

$$dp = 4f \cdot \frac{L}{d} \cdot \frac{u^2}{2g} \cdot \rho_g + 1.5 \frac{u^2}{2g} \cdot \rho_g.$$

Introduction of mass rates (G sec. $= u\ \rho_g$) transforms the equation to:

$$dp = (4f \frac{L}{d} + 1.5) \cdot \frac{G^2 \text{ sec.}}{2g\ \rho_g} \cdot \text{psf.}$$

The absolute viscosity of the gas at 725°F is $\mu = 0.032$ cps.

$$G \text{ sec.} = \frac{5800}{3600} = 1.61 \text{ lb./sq. ft sec.}$$

$$Re = \frac{d \,.\, G\,\text{sec.}}{\mu} = \frac{2.9 \times 1.61}{12 \times 0.032 \times 0.000672}$$
$$= 18{,}000$$

Fanning friction factor, $f = 0.0075$

The gas density at 725°F is

$$\frac{26}{359} \times \frac{492}{1185} = 0.03 \text{ lb./cu. ft.}$$

$$dp = \left(4 \times 0.0075 \times \frac{10 \times 12}{2.9} + 1.5\right) \times \frac{1.61^2}{64.4 \times 0.03}$$

$\therefore dp = 3.7$ lb./sq. ft (0.71 in. H_2O).

Losses, other than chimney, will be approximated. Using the Fanning equation for the kiln, with its integrated cooling section, will bring nearly 0.2 in H_2O drop; this should be more than doubled because of substantial obstructions. Losses in breeching are small but higher losses may be encountered in the dedusting unit, depending on its design. Allowing also for the departure from clean conditions in the waste-heat boiler, 1.5 in. H_2O will be assumed for the system, chimney excluded.

Specification of the Draught System

A balanced-draught system is proposed for the duty. It will consist of a 150-ft chimney and an air blower. Having established arbitrarily the height of the chimney, the remaining calculation will be confined to the estimation of the chimney's diameter and the power requirement for the blower. The latter will be evaluated from the total resistance (between the discharge-end of the cooler and the chimney base, estimated already for 1.5 in H_2O), after deducting the net draught produced by the chimney, as follows:

A rough estimation of the mean temperature of the gases (taking 0.5°F drop a foot) indicates 6-ft chimney diameter at 30 fps economic velocity basis. From Fig. 3, the factor is P 0.805 (for $H = 150$ and $D = 6$ ft). Assuming $t_g' = 650$°F, for the flue gases at the base of the chimney (heat losses between the waste-heat boiler and the base being neglected), the mean temperature from Equation (8) is $t_g = P \times t_g' = 522$°F.

The mean density of the flue gases ($M_{av.} = 26$) is:

$$\rho_g = \frac{26}{359} \times \frac{492}{982} = 0.0363 \text{ lb./cu. ft.}$$

and the volumetric rate of flow is:

$$\frac{29.56}{0.0363}\left(\frac{\text{lb./sec.}}{\text{lb./cu. ft}}\right) = 814 \text{ cu. ft/sec.}$$

As outlined previously, for such a capacity, 30 fps is to be taken as an economic mean velocity. On this basis, the cross-section of the chimney would be $\frac{814}{30} = 27.1$ sq. ft, corresponding to 5.87 ft diameter. With a small allowance for air leak, the chimney diameter will be made $D = 6$ *ft*.

From the left-hand side of Equation (1) the theoretical draught produced by the chimney is:

$H(\rho_a - \rho_g) = 150\,(0.075 - 0.0363) = 5.8$ psf $\equiv 1.12$ in. H_2O.

where

$\rho_a = 0.075$, is the air density at 70°F.

The net draught is obtained from this value by subtracting the energy losses, in the chimney only, due to friction (h_c) and velocity head.

The loss due to friction in the chimney, from Equation (9), is:

$$h_c = (1 + 0.09 \,.\, H/D) \,.\, \frac{u^2}{2g} \,.\, \frac{\rho_g}{5.2} \text{ in. } H_2O$$

$$= \left(1 + 0.09 \,.\, \frac{150}{6}\right) \cdot \frac{30^2}{64.4} \cdot \frac{0.0363}{5.2}$$

$\therefore h_c = 0.33$ in. $H_2O \equiv 1.72$ psf.

The velocity head is:

$$\frac{u^2}{2g} = \frac{30^2}{64.4} = 14 \text{ ft.}$$

This is equivalent to:

$$14 \times 12 \times \frac{0.0363}{62.4} = 0.098, \text{ say, } 0.1 \text{ in. } H_2O.$$

The net draught produced by the chimney is thus:

$$1.12 - 0.33 - 0.10 = 0.69 \text{ in. } H_2O.$$

The remaining loss to be covered by the blower is equal to:

$$1.5 - 0.69 = 0.81 \text{ in. } H_2O \equiv 4.22 \text{ psf.}$$

The volumetric rate of (20.6 lb./sec.) air at 70°F is:

$$\frac{20.6}{0.075} = 275 \text{ cu. ft/sec.}$$

With 50% over capacity the theoretical horse-power is:

$$\frac{275 \times 4.22}{550} \times 1.5 = 3.1 \text{ hp.}$$

Assuming, with Williams,[2] 60 to 65% efficiency, the actual power requirement will be met by a 5-hp motor. The following is therefore the equipment specification: a 5-hp blower of 16,500 cfm capacity, in addition to a brick chimney of 150 ft height and 6 ft diameter, is required.

Although objections may be levelled on the inclusion of the waste-heat boiler on economic grounds in the worked example, this does not detract from the usefulness of the method demonstrated. Moreover, the use of waste-heat boilers in dry processes is quite common in America.[8] According to this reference, although the useful application of low-grade heat in wet processes presents some difficulties, the decision to employ waste-heat boilers may be dictated by the availability of cheap power from an outside source. It could be argued that the fan could be replaced under the conditions of the problem by an additional 100 ft of chimney. It has been included in the problem, therefore, to show the general method of tackling balanced-draught systems. At the same time, it may be remarked that some planning authorities put a limit to the height of chimney which can be erected within districts which come under their surveillance.

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B.O.L.'s Orders Exceed £3 million

A REVIEW OF CONTRACTS placed in the past few months for tonnage oxygen plants reveals that British Oxygen Linde has received export orders for tonnage oxygen/nitrogen installations worth over £2½ million. Other orders received by the company in this keenly competitive field include two installations for the Shell Group of companies in the United Kingdom, due for completion early in 1958, and a further order, worth some £800,000, for a plant with a combined daily output of 275 tons of oxygen and 285 tons of nitrogen to be erected at Modderfontein for African Explosives & Chemical Industries Ltd. It is to be used to extend capacity for producing ammonia by the synthesis process, involving the use of oxygen gasification for hydrogen production. Of the two home orders nearing completion, that at Shell Haven is to supply oxygen and nitrogen for ammonia manufacture.

CEMENT BY A SEMI-DRY PROCESS

THE new Blue Circle Group's Cauldon cement works at Waterhouses, Staffordshire, claimed to be the most efficient and up-to-date plant of its kind in the world, was officially opened by the Minister of Works, Mr. Hugh Molson, at a ceremony in Staffordshire recently. It is the first large-scale factory in Great Britain to employ a semi-dry process. As the name suggests, this process uses less water than the wet method, which is commonly used in Britain, and it leads to considerable economy in the fuel used for evaporation. The first few weeks' performance of the new plant has shown that the Group's hopes of fuel saving will be fulfilled, and it is expected that only 15 tons of fuel will be required for each 100 tons of product, compared with 25 tons for each 100 tons by the wet method. The power consumption is found to be "about the same" in the two methods. The essential practical difference between the two processes is that in the semi-dry method the mixed materials for kilning are made into damp, clay-like nodules containing only 12% of water, instead of into a slurry composed of 40% of water. The nodules are pre-heated on a grate before being roasted, and the rotary kiln is shorter than that used in the wet method.

Cleanliness is an outstanding feature of the Cauldon plant. This good housekeeping is achieved partly because little dust is produced in the kiln stage and partly because of the care that has been taken to extract dust at every part of the process, and, in general, to make the works fit in with its beautiful surroundings on the edge of the Peak District National Park. Non-productive expense incurred to meet the amenities of the district has amounted to between £350,000 and £400,000—a little over 10% of the total cost of the plant. The aerial effluent from the plant, including crushers, has been reduced to the point that, during warm weather, none at all is visible. At other times only a small plume of excess steam is seen (as shown in the illustration above). Automatic control is used widely throughout the factory, and the whole process employs only 100 men divided among three shifts.

The main raw materials, carboniferous shale and limestone, are quarried close to the site, and are crushed in separate plants. Reduced to about 1-in. mesh, they are carried to the processing plant by belt conveyors and there they are first dried and ground in two edge-runner mills, hot-air swept. The mills for this process, by Pfeiffers, are each capable of processing 35-40 tons per hour to 6% residue on 170 mesh. Hot air for each mill is provided by a separate pulverised-fuel furnace. Its supply is automatically regulated in quantity and temperature and provision is made for an emergency cold-air bleed which opens should an excessive temperature be reached at the mill inlet. The fine "meal" produced in each mill is drawn upwards through a classifier and the fines then pass to a collecting unit consisting of a Davidson mechanical precollector and a Sturtevant electrostatic precipitator.

The granulators, housed in a 116-ft-high building at the south end of the kiln group, consist of two inclined revolving dishes 12 ft in diameter and 3 ft deep. Their inclination may be varied over a wide range, and they are fitted with crank-operated oscillating scraper gear. They receive meal from feeders in which a constant head is maintained, and water is supplied to each dish by a pump coupled to the variable-speed drive of the feeder. As the pumps are of the variable-displacement type, the water : meal ratio may be varied as necessary to produce good nodules. The damp nodules are discharged to a double-pass Lepol kiln grate on which they are subjected to hot gases drawn from the kiln. As the nodules are conveyed towards the kiln, they are dried and partly calcined. Gradual heating prevents their disintegration. The granulator and grate plant were supplied by Polysius, who own the patent right for the process.

The rotary kiln, by Vickers-Armstrongs, is of all-welded construction, 152 ft long by 12 ft 6 in. inside shell diameter, and it is fired by pulverised coal. The maximum temperature reached is about 1450°C. The guaranteed output of grate and kiln is 500 tons per day. Clinker from the kiln is discharged into a double-pass grate cooler capable of cooling 700 tons of clinker per day down to a temperature of 170°F. An electrostatic precipitator removes the small amount of entrained dust borne by the gases emerging from the pre-heating grate.

The final process in cement making—the grinding of clinker and gypsum—is conducted in two cement ball-grinding mills 45 ft long and over 8 ft in inside diameter, each having an output of about 30 tons an hour.

The cauldron plant is planned to produce 200,000 tons of cement annually. Although the cost of building it (£3.5 million) has been described by Mr. Geoffrey Davis, managing director of the Blue Circle Group, as "inordinately high", the expenditure is expected to be justified by the economies in the process.

THERMODYNAMICS AND TRANSPORT PROPERTIES OF LIQUIDS

Summaries of selected papers presented at the recent London conference on the thermodynamics and transport properties of fluids are given below

THERMAL AND ELECTRICAL CONDUCTIVITIES OF MOLTEN METALS

by R. W. Powell and R. P. Tye

NEW DETERMINATIONS have been made by the thermal and electrical conductivities of lead, bismuth and the lead-bismuth eutectic from their melting points to about 500 to 600°C (932 to 1112°F.). The apparatus was a modification of the longitudinal heat-flow apparatus normally used for comparative measurements of the thermal conductivities of metals in the solid phase. The molten metal is contained in a thin walled tubular extension of the lower standard bar and the heat flow to and from this section derived from temperature gradients established in metal bars of known thermal conductivity. For the measurements on lead these bars were of 0.8% carbon steel, but stainless steel was used for bismuth and for the eutectic. Measurements of the electrical resistivity were also made for the purpose of ascertaining the extent to which the Wiedeman-Franz-Lorenz relationship is obeyed by these liquid metals. Results appeared to show, in agreement with other recent data, that the thermal conductivities of molten metals can be predicted from their electrical resistivities with a fair degree of certainty by using the theoretical value of the Lorenz function. More work clearly needs to be undertaken in this field, but the results of the present decade indicate that the uncertainty accompanying this method of derivation is unlikely to exceed 15% and will for many metals be within half of this figure.

HEAT CONDUCTIVITY AND CHEMICAL REACTIONS IN GASES

by I. Prigogine and F. Waelbrock

THE THERMAL conductivity of various gases has been measured between 8×10^{-3}mm of mercury and about 3 atm. The apparatus consisted of two coaxial cylinders of comparable diameters. In order to distinguish between Knudsen and dispersion effects (which depend on the apparatus size) on the one hand, and other factors, such as the Euskog effect, which are independent of these dimensions, three pieces of apparatus which differed only in size were built. The cylinder diameter ranges were 13/23, 18/22, and 20/22 mm, respectively and the inner cylinders were approximately 110 mm high. Results indicated that for diatomic molecular hydrogen, H_2 and oxygen O_2, the rotational energy transfer decreases sharply at low pressures. This decrease can be interpreted if about one collision out of 200 for H_2, one out of 20 for O_2 brings about a translational-rotational energy exchange. This result agrees with the velocity of sound measurements.

THE GAS IMPERFECTIONS OF HYDROCARBONS

by H. G. David and S. D. Hamann

IN THE PAST 20 years there have been a large number of measurements of the P-V-T properties of hydrocarbon gases. Since the results have a theoretical as well as a practical value, the field has been reviewed and the data reduced to a convenient form eliminating the multiplicity of units used in the original papers. The present authors have chosen to fit the experimental isotherms to the relation

$$\frac{PV}{RT} = Z = 1 + \frac{B}{V} + \frac{C}{V^2} \qquad \ldots.(1)$$

where P denotes the pressure, V the molar volume and T the absolute temperature of the gas; R is the gas constant and B and C are constants for each isotherm. The equation may be rewritten as

$$Z = 1 + \frac{B^*}{V^*} + \frac{C^*}{V^{*2}} \qquad \ldots.(2)$$

where $$B^* = \frac{B}{V_c},\ C^* = \frac{C}{V_c^2},\ V^* = \frac{V}{V_c}$$

V_c being the critical volume of the gas. Equation (2) gives an adequate representation of the behaviour of the lower hydrocarbon gases so long as V^* is greater than 1.3. In these circumstances B^* and C^* can be identified with the second and third virial coefficients in the infinite series

$$Z = 1 + \frac{B^*}{V^*} + \frac{C^*}{V^{*2}} + \ldots$$

By the principle of corresponding states they should be universal functions of the reduced temperature $T^* = T/T_c$ where T_c is the critical temperature.

By rearranging Equation (2) it can be seen that a plot of $(Z - 1)\,V^*$ against $1/V^*$ should be a straight line of slope C^* and intercept B^*. Most of the experimental data satisfy these requirements when $1/V^*$ is less than 0.8, but a few give plots that curve badly at small values of $1/V^*$. The reduced second virial coefficients of the straight chain alkanes when plotted as functions of the reduced temperature show steadily increasing deviations from the behaviour of the inert gases as the chain length increases (apart from some anomalous results for pentane). In

contrast, the values of B^* for the straight chain alkenes show no regular trend with increasing chain length. The curves for ethene, propene and 1-butene are all nearly coincident with that for propane.

THE THERMODYNAMIC PROPERTIES OF THE NORMAL ALCOHOLS

by L. W. Shemilt

THE THERMODYNAMIC properties of the first four members of the aliphatic series of the normal primary alcohols were considered, and calculated values for methanol and ethanol related to recently measured and calculated values for n-butanol; values for n-propanol were predicted. It was concluded that graphical interpolation between known values of thermodynamic properties for members of this series when based on molar quantities and referred to the same reduced temperature gave values for the unknown members, in this case n-propanol, that are apparently within 2 to 3% accuracy. Volumes, entrophies and enthalpies for the saturated region can be calculated in this way and the thermodynamic network thus portrayed. The successful use of a group contribution method to extend such calculations to the higher members of the series appears dubious beyond extension to the next unknown member (in this case, n-amyl alcohol). The reduced temperature basis for the calculations requires a knowledge of the critical temperature. This and the other critical properties can be calculated by the use of empirical equations based on group contributions. The equations are considered valid up to at least n-octyl alcohol with an average deviation of not more than 0.4% for critical temperature and 1.0% for critical pressure and critical volume.

MEASUREMENTS ON THERMAL DIFFUSION IN HYDROGEN-NITROGEN MIXTURES AS A FUNCTION OF PRESSURE

by A. van Itterbeek and W. de Rop

WHEN A TEMPERATURE gradient is established in a gas mixture a concentration gradient appears. The change of concentration is given by the equation

$$\triangle x = k_T . \log_e T_1/T_2$$

where T_1 corresponds generally with room temperature, T_2 the high or low temperature and $k_T = R_T.x(1-x)$; R_T being the thermodiffusion ratio and independent of temperature except at low temperatures. Measurements have been carried out to examine the effect of pressure on this change at 229°K., the boiling point of liquid proprane, and at 90°K, the boiling point of liquid oxygen, at pressures up to eight atmospheres. In the near future the measurements will be extended to higher pressures. The change in concentration was measured by means of an ultrasonic interferometer enabling the very high precision of about 1 in 10,000 to be obtained. Allowance was made for the non-ideality of the gas at high pressures. As an illustration of the magnitude of the effect it may be quoted that at a composition of 45.5% H_2/54.5% N_2 and 229°K, pressure 8 atmospheres, $\triangle x$% was 0.39. The increase with pressure at 90°K' is about 0.8% per atmosphere.

MEASUREMENT OF THE VISCOSITY OF COMPRESSED NITROGEN UP TO 3000 ATMOSPHERES

by F. Lazarre and B. Vodar

A FLOW METHOD has been used employing a capillary for measuring the viscosity of nitrogen up to 3000 atmospheres at 25, 50 and 75°C. The flow is produced by the displacement of a mercury level which is controlled by a plunger operated by an electromagnet coil. The mercury level is located by means of five electrodes in a container connected to the direct viscometer tube. When the mercury comes into contact with the electrodes it changes the blocking voltage of a thyratron. The latter controls the operation of a printing chronograph having an accuracy of 1/100 sec., and this gives the time of passage of the mercury at the different levels. The variation of viscosity was measured as a function of pressure. A selection of the figures obtained is quoted below:

Viscosity of nitrogen in Poise × 10^{-6}			
Pressure kg./sq. cm.	Temperature, °C.		
	25	50	75
1	177	187	198
1000	526	488	472
2000	868	772	740
3000	1195	1052	—
3250	1280	—	—

These results are in agreement within less than 1% with those of Michels and Gibson (1932), up to 1000 kg./sq. cm. in common pressure ranges.

Meetings of the Month

The Institute of Metals

November 7. *London Local Section:* At the Royal School of Mines, South Kensington, London, S.W.7. "Refractories", by J. White, D.Sc. **7 p.m.**

November 7. *Leeds Metallurgical Section:* At the Yorkshire Copper Works Ltd., Leeds. "The Development of Electronics for Process Control and Inspection", by C. H. Gould. **7.15 p.m.**

November 7. *East Midlands Metallurgical Society:* At the Nottingham and District Technical College, Shakespeare Street, Nottingham. "Rare Metals", by J. C. Chaston, B.Sc., Ph.D., F.I.M. **7.30 p.m.**

November 11. *Scottish Local Section:* At the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2. "Vacuum Metallurgy", by F. C. Weil, Ph.D., Dr.Ing. **6.30 p.m.**

November 12. *Oxford Local Section:* At the Cadena Café, Cornmarket Street, Oxford. "Recent Advances in Ironmaking", by a staff member of the British Iron and Steel Research Association. **7 p.m.**

November 12. *South Wales Local Section:* At the Royal Institution, Swansea. "Nuclear Power", by L. Rotherham, M.Sc., F.Inst.P., F.I.M. **7 p.m.**

November 13. *Liverpool Metallurgical Society:* At the Picton Library. "Application of Inert Gas Electric Arc Welding", by P. J. L. Leder, M.Sc. **7 p.m.**

November 14. *Liverpool Metallurgical Society:* At the Liverpool Engineering Society, 9 The Temple, Dale Street, Liverpool. "Corrosion and Microstructure", by C. Edeleanu, M.A., Ph.D. **7 p.m.**

November 14. *North-east Metallurgical Society:* At the Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. "Fatigue", by N. Thompson, Ph.D. **7.15 p.m.**

November 21. *Birmingham Section:* At the Birmingham Exchange and Engineering Centre, Stephenson Building, Newcastle. "Metallurgical Thermodynamics", by J. N. Pratt, B.Sc., Ph.D. **6.30 p.m.**

The Physical Society

October 31. *Low Temperature Group:* "Reports on the 5th International Low Temperature Conference". Place and time to be announced.

November 15. *Acoustics Group:* At Pametrada Laboratories and King's College, Newcastle upon Tyne. A Symposium on "Flow Noise". Until November 16.

STEAM TRACING OF PIPELINES

Pipelines for the transport of fluids likely to freeze at ordinary temperatures require heating. Steam tracing offers an economical solution

by EDMUND BARTON, M.A., and ELIZABETH V. WILLIAMS, B.Sc.

STEAM is widely used for heating pipelines carrying process materials which would freeze at ordinary atmospheric temperatures. Either jacketing or tracing may be suitable and the tracing may be run adjacent to the process pipe without welding if low temperatures only are required, or may be attached by welding if high heat rates and high temperatures are necessary. If the process-pipe temperature is required to approach very closely that of the available steam, jacketing may be essential, but otherwise, at least for process-pipe diameters up to and including 4 in., steam tracing will be cheaper than jacketing. For larger diameters the cost of traced piping may exceed that of jacketing, as more than one tracing pipe would normally be required.

The design of jacketed piping is straightforward and is not considered in detail here. The detailed design of steam tracing has been investigated theoretically by P. G. Andrews and I. J. Robinson, of I.C.I., Dyestuffs Division, and a simplified version of their design procedure is put forward here. Tests have been carried out by I.C.I., Billingham Division, which show that the heating provided by this method is more than adequate.

Tracing for High Temperatures

The practice of wrapping copper tubing which conveys the heating fluid around the process pipework is not to be recommended and, furthermore, it is quite ineffective if the process material solidifies at a relatively high temperature.

If a considerable heating rate is required to melt out a frozen pipeline rapidly, the tracing pipe must be welded to the process pipe. As most of the heat is transferred through the welds, the main design feature to be determined is the pitch of the short runs of welding. The spacing of the steam traps on the tracing pipe is also an important feature of the design. The charts have been constructed to allow these two features of design to be readily obtained for pipework of specified type and material, temperatures of steam and product melting point, and for appropriate rates of heat input.

Heat Input Rate

Heat must flow from the tracing to the process pipe to supply heat lost through the lagging from the surface of the process pipe. For simplicity the charts have been constructed to take account of heat losses at a process pipe temperature of 160°C, through a layer of 85% magnesia 1½ in. thick and ½ in. of hard-setting compound, giving a total thickness of 2 in. of effective thermal conductivity 0.56 CHU/hr sq. ft °C/in.; 50% has been added to this heat loss to allow for lagging imperfections. For heat loss conditions different from the above, another method, described later, can be used.

Should the contents of the process pipe become solidified through some misadventure, e.g., failure of steam, heat must be supplied to melt out the frozen material in a reasonable time. In cases where the process must be kept running continuously, for example in a high-temperature distillation, it is safer to rely upon jacketing for maintaining the process stream in the fluid state. For a melting-out time of one hour and for a range of values of the latent heat of fusion and density of the product, the required heat rate per foot run of the various sizes of piping has been calculated. For heat flow from the pipe wall to the process material, a heat-transfer coefficient of 20 CHU/hr sq. ft °C was assumed. A design method is suggested if melting times other than one hour are to be allowed for.

Symbols

L_p = latent heat of fusion of process material, CHU/lb.
W_p = density of process material, lb./cu. ft.
T_o = melting point of process material, °C.
T_s = temperature of saturated steam, °C.

Mechanical Construction of Tracing

The rates of heat flow from the tracing to the process pipe used in the charts are based on mild steel construction for British Standard Class B piping, and for welds as illustrated in Figs. 1, 2 and 3. The type of fillet weld shown could be laid down, for instance, by two runs with an 8-gauge rod. A design method for materials of construction other than mild steel is also proposed, on the basis that the heat flow through the welds and pipe walls will be in proportion to their thermal conductivities.

The charts are based on welds of 1 in. length on both sides of the tracing pipe, or, alternatively, welds of 2 in. length on alternate sides of the tracing pipe, using a single tracer. The charts, therefore, show the necessary spacing of these welds along the piping, or, for the extreme case, indicate that continuous welding is necessary on both sides of the pipe.

Flanges are the most vulnerable points in the pipeline,

Mr. Barton *studied mechanical sciences at Cambridge University from 1937 to 1940. He is at present with the chemical engineering section of I.C.I.'s Dyestuffs Division, Huddersfield.* **Elizabeth V. Williams** *obtained her B.Sc. at London University. She joined the chemical engineering section of I.C.I.'s Dyestuffs Division, Huddersfield, on leaving college.*

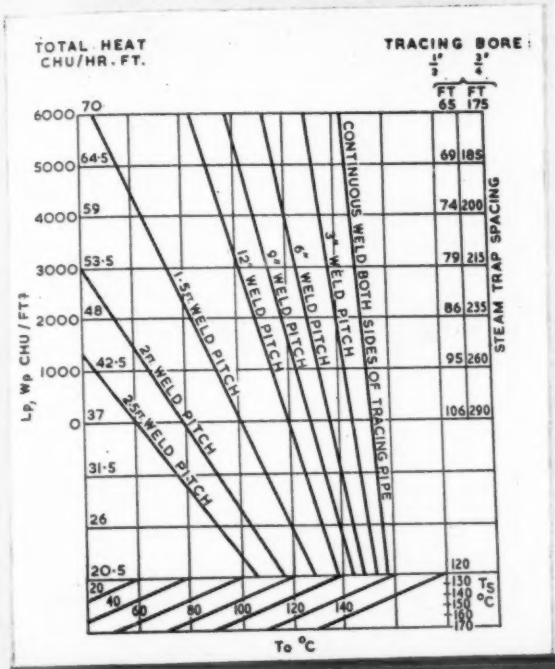


Fig. 1. Determining details of fillet welding for fixing tracing pipe to process pipe. This chart refers to 1-in. B.S.S. Class B process pipe.

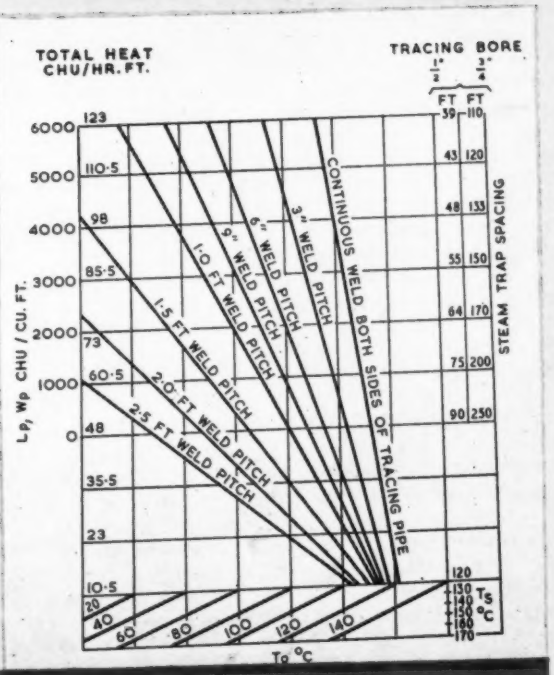


Fig. 2. Determining details of fillet welding for fixing tracing pipe to process pipe. This chart refers to 1½-in B.S.S. Class B process pipe.

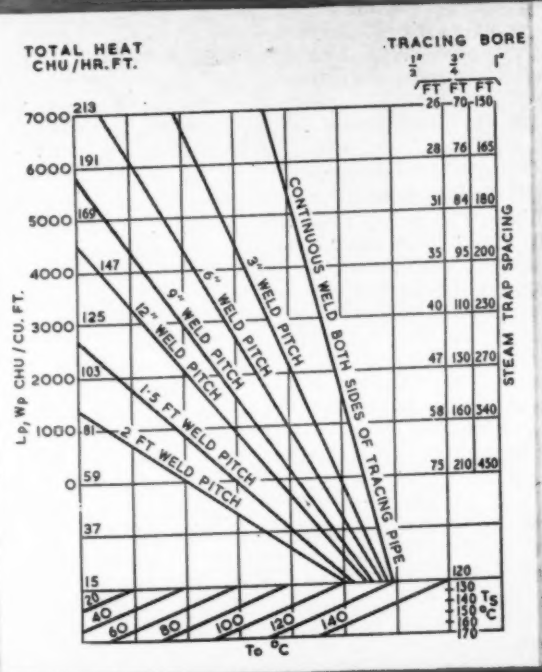


Fig. 3. Determining details of fillet welding for fixing tracing pipe to process pipe. This chart refers to 2-in. B.S.S. Class B process pipe.

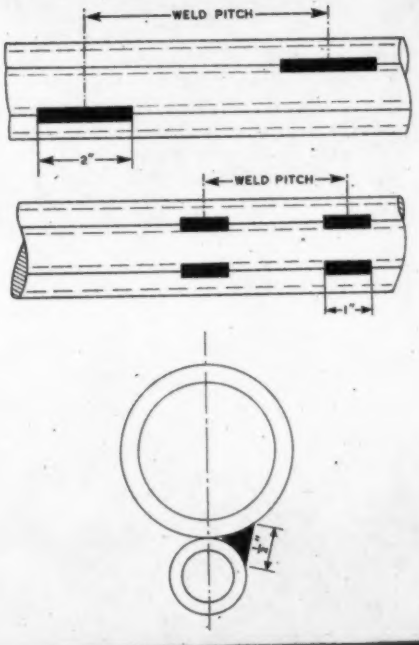


Fig. 4. Layout of fillet welding for attaching tracing pipe to process pipe. Note that two procedures can be used.

as they expose a large surface of metal for heat loss through the lagging. The designer can make an allowance for this loss by laying down extra welding near the flanges. The amount of extra welding will depend on the severity of conditions, and a recommendation is made in the section on Design Procedure. Two methods by which suitable tracing pipe connections may be made at process pipe flanges are illustrated in Figs. 8 (a) and 8 (b). In Fig. 8 (b) the chasing pipe is taken up to the flange and welded to the process pipe, and the steam connection is made by welding on a branch pipe at a minimum distance from the flange. In the system shown in Fig. 8 (a) oval flanges are used, both the process and tracing pipes being welded into suitable drillings in the flange. Separate joint rings are used for the two fluids to avoid any danger of leakage from one to the other. The latter method is preferable, as considerable heat quantities can be supplied to the flanges, and the disturbance to lagging is a minimum. However, it is only practicable if facilities are available for profile flame cutting.

Steam-trap Spacing

The flow of steam into each section of tracing pipe is at a maximum when frozen material is being melted out, as heat is then being lost from the tracing and process pipes and is also being used for melting. During this stage the design must ensure that not only is the distance between steam traps small enough to cause only a small drop in steam pressure, but also that the condensate shall drain freely in the line. The steam-trap spacing shown on the design charts is calculated for drainage of condensate in a line with a slope of 1 in 60, so that the tracing pipe is not more than one-third full at any point. This condition gives a steam pressure drop of less than 1 lb./sq. in.

To obtain the minimum pressure drop in the tracing-pipe loops round process pipe flanges, the loops should run either horizontally or below the process pipe. The use of one steam trap for more than one length of tracing pipe must be avoided.

Design Procedure

(*a*) *Mild-steel Piping and Standard Conditions.* Assume that, for process piping of 4 in. in diameter or less, steam tracing may be used in preference to jacketing. Look up the saturated steam temperature, T_s, and the relevant properties of the process material—freezing point, T_o, latent heat of fusion, L_p, and density, W_p. Plot the point corresponding to the value of the product of latent heat of fusion and density, L_pW_p, and the values of T_o and T_s on the chart for the appropriate process-pipe diameter.

Fig. 5. Illustration of tracing system of Fig. 8, using Crownall couplings.

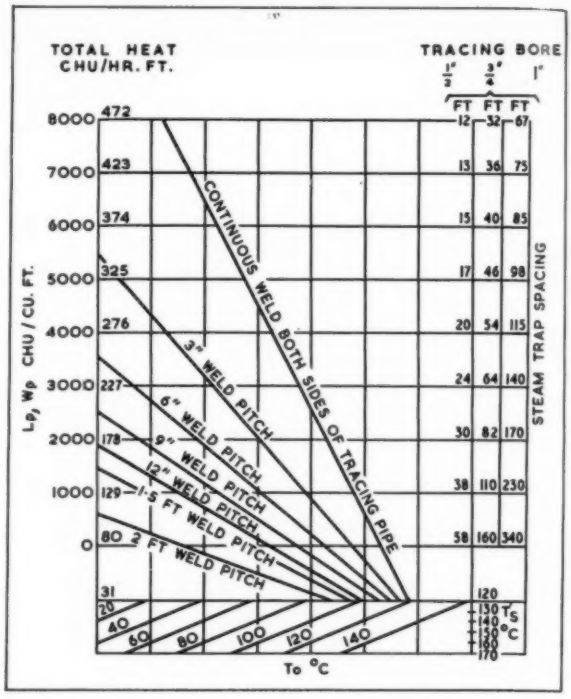


Fig. 6. Determining details of fillet welding for fixing tracing pipe to process pipe. This chart refers to 3-in. B.S.S. Class B process pipe.

The nearest line above this point will give the required weld pitch. Use welds of 1 in. length on both sides of the tracing pipe, or, alternatively, welds of 2 in. length on alternate sides of the tracing pipe as shown on Figs. 1 and 2, using a single tracer. Continuous welding, if indicated, is only suitable for runs of piping without flanges. Extra welding should be added at flanges up to a length of 8 in. on both sides of the tracing pipe, brought up to the flange faces for the arrangement of Fig. 8 (b), or within about 2 in. of the flange for the arrangement of Fig 8 (a).

Steam-trap spacings are shown on the scales on the right of the charts for the particular size of tracing pipe chosen; the spacing is found by running horizontally from the value of the product L_pW_p used above for weld pitch. Plastic magnesia lagging of $1\frac{1}{2}$ in. thickness without any preparatory wrapping of the pipe, covered by $\frac{1}{2}$ in. thickness of hard-setting compound, will provide satisfactory insulation.

If the traced piping system is to be used for such materials as caustic soda or strong sulphuric acid, a stress-relieving heat treatment should be carried out after welding to prevent local attack near the welds. The extra cost of this treatment amounts to no more than about 5%.

(*b*) *Piping other than Mild Steel and Non-standard Conditions.* In the design method given in (*a*), it has been assumed that heat flows from the tracing to the process piping solely by conduction through mild-steel welds and pipe walls. For materials other than mild steel, the product of the latent heat of fusion and the density of the process material should be calculated as before. The total heat requirement per ft run, i.e., the sum of the heat required for melting and of the heat losses through the lagging, should then be found from the total heat scale on the chart, for this value of L_pW_p. This total heat requirement must be multiplied by the ratio of the thermal conductivity of mild steel to that of the actual pipe material, and this adjusted figure used on the total heat scale in conjunction with the saturated steam temperature

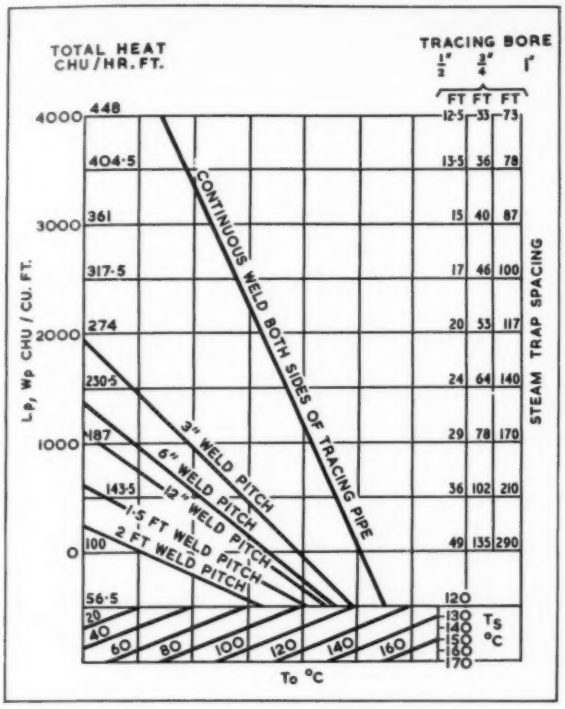


Fig. 7. Determining details of fillet welding for fixing tracing pipe to process pipe. This chart refers to 4-in. B.S.S. Class B process pipe.

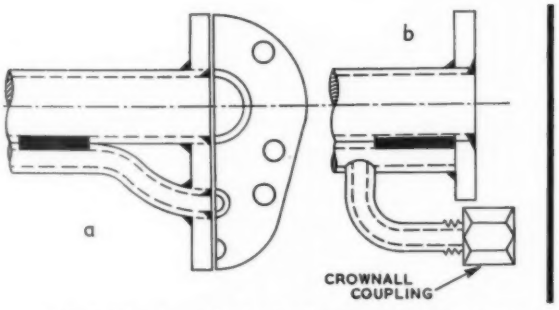
and the melting temperature to find the weld pitch. This procedure does not apply to the steam-trap spacing, which may be found from the product of the latent heat of fusion and the density of the process material as before.

The charts are based on heat supply through the welds sufficient to melt out a frozen pipeline in one hour and to counter heat losses with a process-pipe temperature of 160°C, allowing also a 50% margin for lagging imperfections. The heat loss per ft run of the pipeline is the figure on the total heat scale corresponding to zero on the L_pW_p scale. Thus, if heat losses at some pipe temperature other than 160°C are to be allowed for, the heat loss figure may be altered in proportion. Similarly, for any desired melting time other than one hour the following method should be used. The value of L_pW_p is obtained and the difference between the total heat at this value and at zero L_pW_p is divided by the desired melting time in hours. The total heat difference so found is added to the heat loss to give a new value of total heat, and this is used in conjunction with T_s and T_o to give the required weld pitch. The steam-trap spacing may also be found from this new value.

Tracing for Low Temperatures

When steam tracing is designed as described above, the heat supply to the process pipe is usually such that the steady-state temperature will closely approach that of steam temperature, and account should be taken of this in choosing the steam pressure if the process material is sensitive to temperature, or has a low boiling point, or if corrosion is an important factor. Thus it is sometimes necessary to use steam at pressures below atmospheric with a vacuum condensate system, or more usually hot-water circulation combined with close weld pitch and connections for the tracing pipe as shown on Figs. 8 (a) and 8 (b). For materials with freezing points only a few degrees above the lowest atmospheric temperatures, steam tracing is sometimes run adjacent to the process pipe without weld attachment, and with a minimum wrapping of lagging. Experience has shown that with only 1 in. of lagging, necessary to prevent excessive heat losses steady-state temperatures within 20°C or 30°C of steam temperature can result.

As already noted, high process-pipe temperatures may be undesirable, but the considerable expense of a complex warm-water circulating system, which can give a very close control of pipe temperatures, cannot always be justified. It is possible to use steam at pressures above atmospheric to maintain process-pipe temperatures at a low level, if the heat supply to the pipeline is regulated by filling the gap between the tracing and process pipes with plastic lagging, and provided heat losses from the process pipe are similarly limited by insulating the whole assembly. Such an arrangement is shown in Fig 9, in which the tracing pipe is spaced away from the process pipe, clipped in position, and the gap made up by 85% magnesia plastic lagging. When the plastic lagging has been completely dried by application of steam to the tracing pipe, the whole is wrapped with asbestos felt and finally protected by a waterproof felt covering. With this system, process-pipe temperatures will obviously be considerably affected by variations in atmospheric conditions, so that a very close control is not possible. Experiments have been made with 1-in. bore and 2-in. bore process pipe, using ½-in. bore tracing with steam at 130°C and plastic filling in the gap between the process and tracing pipes; the whole assemblies were wrapped with two layers of ½-in. asbestos felt and finally with a waterproof covering. With a gap of ½ in. between the two pipes, process-pipe temperatures were between 40°C and 50°C above ambient temperature, and with a gap of ¾ in. the excess temperature was between 30°C and 40°C. Steady-state temperatures were reached in about three hours.



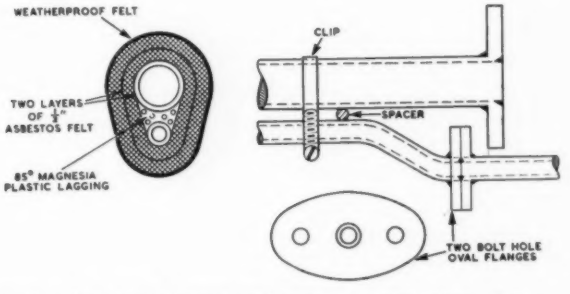


Fig. 8 (a). A method of allowing for heat losses at flanges using oval flanges and separate joint rings. Fig. 8 (b). An alternative method of allowing for heat losses at flanges. A branch is welded to the tracing pipe close to the flange. Fig. 9 (right). A system of tracing suitable for maintaining process pipe and contents at temperatures appreciably lower than the steam temperature.

RUSSIAN ARTICLES ON CHEMICAL ENGINEERING (I)

A select list of articles on chemical engineering or allied subjects which have appeared in the Russian literature during the past two years is presented below. It is intended to publish further lists from time to time, depending upon the number of articles on these subjects appearing in the Russian literature.

General Description of Subject Matter	Title of Article (Free Translation)	Authors	Journal
Heat transmission and related subjects.	Heat transfer in flow along tube nests.	A. Ya. Inayatov and M. A. Kikheev.	Teploenergetika (Heat Energy), 1957, No. 3, p. 48.
Heat transmission and related subjects.	Heat transfer by radiation from a stream combustion product in a channel.	V. A. Adrianov and S. N. Shorin.	Teploenergetika (Heat Energy), 1957, No. 3, p. 50.
Heat transmission and related subjects.	Heat transfer in a foam apparatus.	I. P. Mukhlenov and E. S. Tumarkina.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 2, p. 135.
Heat transmission and related subjects.	Heat exchange in a foam apparatus.	I. P. Mukhlenov and E. S. Tumarkina.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 4, p. 345.
Heat transmission and related subjects.	Heat exchange during viscous movement of a liquid in pipes and channels.	B. S. Petukhov, E. A. Krasnoshchekov and L. D. Nol'de.	Teploenergetika (Heat Energy), 1956, No. 12, p. 41.
Heat transmission and related subjects.	Effect of convective heat transfer and inertia forces on heat exchange in laminar flow of a film of condensate.	D. A. Labuntsov.	Teploenergetika (Heat Energy), 1956, No. 12, p. 47.
Heat transmission and related subjects.	Choice of spacing between the tubes of a heat exchanger.	Yu. L. Vikhman.	Teploenergetika (Heat Energy), 1957, No. 2, p. 38.
Heat transmission and related subjects.	New approximate formula for mean logarithmic temperature differences.	E. P. Shubin.	Teploenergetika (Heat Energy), 1957, No. 2, p. 40.
Heat transmission and related subjects.	Influence of variation of condensate temperature upon heat-transfer ratio for filmwise condensing conditions.	D. A. Labuntsov.	Teploenergetika (Heat Energy), 1957, No. 2, p. 49.
Mixing.	Mixing of volumes of gas with intense jets.	L. A. Vulis.	Teploenergetika (Heat Energy), 1956, No. 12, p. 37.
Mixing.	Assessment of the effectiveness of mechanical mixers for dissolution processes.	V. V. Kafarov and V. D. Podolma.	Khimicheskaya Promyshlennost (Chemical Industry), 1957, No. 2, p. 86.
Mass transfer processes, distillation, extraction, absorption, etc.	Mass transfer through the liquid phase during bubbling through a sieve plate.	I. N. Kuzminykh and Zh. A. Koval.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 1, p. 21.
Mass transfer processes, distillation, extraction, absorption, etc.	The kinetics of absorption through bubbling.	L. A. Mochalova and M. Kh. Kishinevskii.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 1, p. 30.
Mass transfer processes, distillation, extraction, absorption, etc.	Rate of absorption in nitrogen oxides by $Ca(OH)_2$ solutions in high-speed rotating mechanical absorbers.	S. N. Ganz and S. B. Kravchinskaya.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 2, p. 145.
Mass transfer processes, distillation, extraction, absorption, etc.	Investigation of the effect of vacuum on the effectivity of separation by rectification of certain polynuclear compounds from coal tar.	O. Ya. Tsypkina.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 2, p. 185.
Mass transfer processes, distillation, extraction, absorption, etc.	Investigation into absorption processes.	N. Ya. Regak and N. I. Smirnov.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 3, p. 262.
Mass transfer processes, distillation, extraction, absorption, etc.	The kinetics of formation of nitric acid in mechanical absorbers fitted with high-speed rotating impellers.	S. N. Ganz and S. I. Kapturova.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 6, p. 585.
Mass transfer processes, distillation, extraction, absorption, etc.	Determination of absorption rate coefficient of nitrogen oxides in aqueous solutions of nitric acid in mechanical absorbers.	S. N. Ganz, M. A. Iokshin and S. I. Kapturova.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 8, p. 831.
Mass transfer processes, distillation, extraction, absorption, etc.	Comparative appraisal of the performance of packed- and sieve-plate columns and their design.	V. V. Kafarov.	Zhurnal Prikladnoi Khimii (Journal of Applied Chemistry), 1955, Vol. 28, No. 12, p. 1255.
Mass transfer processes, distillation, extraction, absorption, etc.	Continuous diffusers for the extraction of medicinal substances from vegetable materials.	A. G. Natradze and A. M. Plyashkevich.	Khimicheskaya Nauka I Promyshlennost (Chemical Science and Industry), 1956, Vol. 1, No. 4, p. 455.
Mass transfer processes, distillation, extraction, absorption, etc.	On the hydraulic resistance of grid and perforated plates.	V. V. Dilman, et al.	Khimicheskaya Promyshlennost (Chemical Industry), 1956, No. 3, p. 156.
Mass transfer processes, distillation, extraction, absorption, etc.	The effectiveness of a rectification column with grid plates at different throughputs.	M. E. Aerov and Darovskikh.	Khimicheskaya Promyshlennost (Chemical Industry), 1957, No. 2, p. 92.
Mass transfer processes, distillation, extraction, absorption, etc.	Industrial extraction.	V. V. Kafarov and S. A. Zhukovskaya.	Khimicheskaya Promyshlennost (Chemical Industry), 1956, No. 2, p. 107.

GRID-PACKED TOWERS UNDER LIQUID MALDISTRIBUTION

The first performance results published of a grid-packed tower under known conditions of liquid maldistribution are given in this article, together with a calculation applicable to all mechanical-draught cooling towers

by J. W. MULLIN, Ph.D., A.M.I.Chem.E.

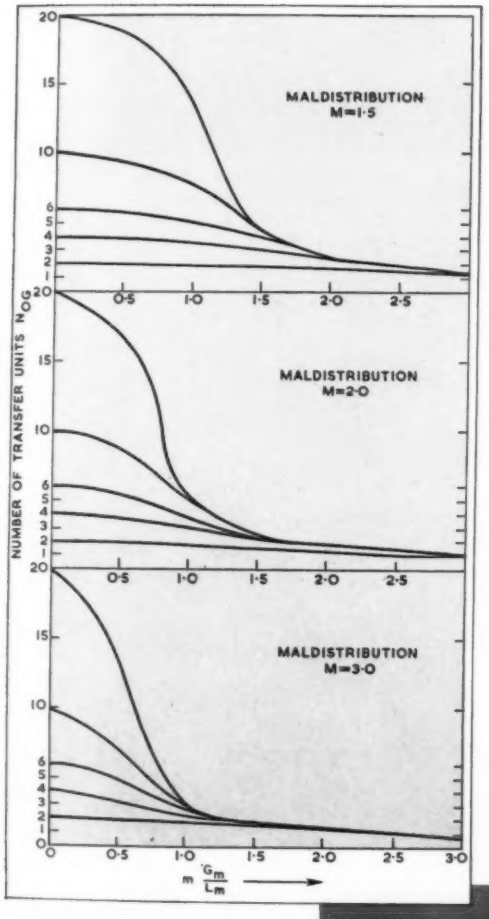
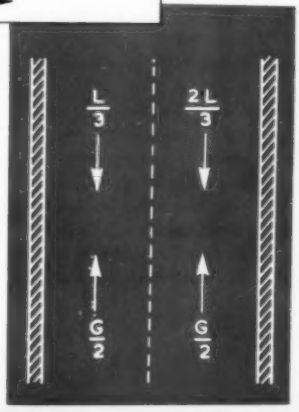


Fig. 1 (right). Diagram of column in which maldistribution of liquid is taking place. Fig. 2 (above). Reduction of number of available transfer units N_{OG} for different degrees of maldistribution with increasing values of the product operating line slope and gas-liquid ratio.



FOR a packed tower to operate efficiently it is essential that the distribution of both liquid and gas should be as uniform as possible throughout the packing. One of the biggest factors contributing to poor performance is the maldistribution of liquid, and the prevention of this undesirable feature is an important aspect in the design of gas-liquid contactors.

The first and obvious step to ensure good liquid distribution in a packing is to install an efficient liquid distributor. However, this often fails to achieve the desired result in random packings, such as rings, etc., because these packings tend to promote wall-flow, i.e., the liquid which is initially distributed uniformly spreads to the walls and remains in this region until it leaves the bottom of the tower. The packing in the centre of the tower becomes liquid-deficient, and a poor performance is almost certain. Precautionary measures to minimise wall-flow can be taken, such as ensuring that the tower : packing diameter ratio is at least 10 : 1[1] and preferably greater than 12 : 1,[2] or spacing the packing in sections and fitting liquid redistributors.[3] Nevertheless, wall-flow will never be completely eliminated in random packings.

Splash-bar packings and spray-fed grid packings may suffer from wall-flow in varying degrees, but film-flow grid packings are generally free from this defect as the grids do not touch the tower walls. Liquid maldistribution can only occur within a film-flow grid packing when either the initial distribution of liquid is non-uniform or when the packing is incorrectly aligned. The levelling and alignment of a grid packing are extremely important; the merest slope in the tower will cause the liquid to migrate to one side of the packing, and this may easily lead to severe wall-flow.

Norman[4] has reported the performance of a 6-in.-square tower packed with carbon grids when liquid was accidently maldistributed due to a faulty distributor. He found that the overall mass transfer coefficient K_G (lb. mol./hr ft^2 atmos.) measured for a water-cooling operation could be correlated by the equations:

$$K_G = \beta\ G^{0.8} \text{ for uniform distribution}$$

and $K_G = \beta'\ G^{0.56}$ for maldistribution

where G is the air rate (lb./hr ft^2). β and β' are dimensional constants depending on the water rate. These were the

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first published results comparing the performance of a packed tower with and without liquid maldistribution, but, unfortunately, the degree of maldistribution was unknown. All that could be said was that an excess of water flowed down one side of the tower.

Maldistribution, by its very nature, is a difficult thing to measure, but a simple form of maldistribution was defined by the author[2] which enabled a theoretical analysis of the phenomenon to be made. Fig. 1 shows a tower which simply has twice as much liquid flowing down one side as down the other. The overall liquid and gas rates are L and G respectively and the gas rate is uniform across the tower. The condition where both halves of the tower carry equal liquid rates, i.e., uniform distribution, is defined as maldistribution $M = 1$. When one half carries twice as much liquid as the other, the maldistribution is defined as $M = 2$, and so on.

These simple definitions can also be applied to a circular tower in which wall-flow occurs; the two theoretical sections of the tower in this case being the outer annulus near the wall, in which much of the liquid flows, and the inner under-wetted circular area. A theoretical analysis was made of the effect of maldistribution on tower performances for gas-film-controlled processes[2] and Fig. 2 shows the expected reduction in the number of available transfer units, N_{OG}, under various degrees of maldistribution with increasing values of the group m (G_m/L_m), where m is the slope of the operating line and G_m/L_m is the molar gas-liquid ratio. These theoretical predictions were found to agree reasonably well with a number of published distillation data, although the actual degrees of maldistribution were not known. It was concluded that maldistribution in any form was serious once the operating value of the group m (G_m/L_m) exceeded 1.0, and that the tendency to maldistribution in random-packed towers increased considerably once the tower : packing diameter ratio became less than 12 : 1.

The object of the present investigation was to determine how the performance of a packed tower varied with known degrees of maldistribution, and the grid packing was a natural choice for this work. Not only could a controlled liquid maldistribution be easily achieved, it could be easily measured. The particular operation chosen was the simultaneous heat and mass transfer between water and air (the evaporative cooling of water).

The Grid Packing

The experimental water-cooling tower used is shown in Fig. 3. The packing consisted of 26 grids, each comprising 16 wooden slats, $\frac{1}{2}$ in. thick, $17\frac{1}{2}$ in. long, $1\frac{1}{2}$ in. deep, pitched at 1 in. and fixed on thin metal spacer rods. To prevent water dripping off the ends of the slats they were cut away to slope in towards the next lower grid. The grids were stacked alternately at right angles to each other in an 18-in.-square glass-lined tower, and considerable care was taken to ensure as uniform an air flow up the packing as possible. Water was fed to four trough distributors resting on the top grid, and each distributor had 16 V-notches in each side so that the water was delivered uniformly on to each slat. Narrow collector troughs were fixed underneath each of the 16 slats in the bottom grid so that the liquid distribution across the tower could be measured, and, during normal operation, 97 to 99% of the water fed to the tower was collected in these troughs, indicating the absence of any serious splashing within the packing. The supply of water to each of the four distributors was independently controlled so that known degrees of maldistribution could be produced quite simply. Fig. 4 shows the arrangement of the distributors, grids and collectors in the tower.

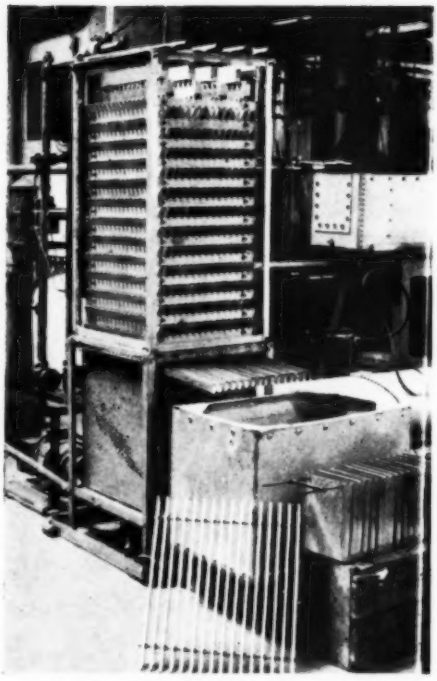

Fig. 3. Experimental water-cooling tower with grid packing consisting of a number of $\frac{1}{2}$-in. × $1\frac{1}{2}$-in. wooden slats pitched at 1-in. intervals.

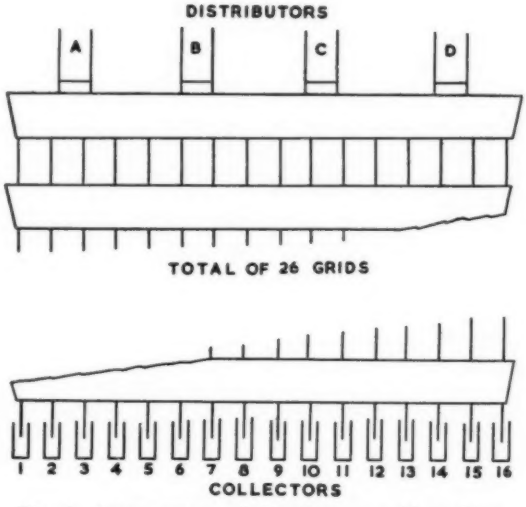

Fig. 4. Arrangement of distributors, grid packing and collectors in the experimental tower.

Temperature and Flow Distributions

Warm water was passed down the tower and cold air was passed up. After steady conditions have been achieved, the temperatures of the inlet water and air (wet and dry bulb) were measured. The flow rates and temperatures of the 16 streams of water leaving the tower were also measured, this operation being facilitated by a portable collector-box arrangement. Wet- and dry-bulb temperatures of the exit air were measured at five points across the tower at positions between but just above the slats, and this was done with an explorer tube attached to a wet- and dry-bulb thermometer chamber through which the air

was drawn at a rate of more than 10 ft/sec. by means of a small fan.

Figs. 5, 6 and 7 illustrate some typical temperature and flow-rate traverses. Fig. 5 shows the temperatures and flows when all four distributors delivered equal amounts of water at a total rate of 2800 lb./hr (1250 lb./hr ft²). This condition is referred to as maldistribution $M = 1$ as defined above. The top graph shows the exit water temperatures across the tower for four different air rates ranging from 1550 to 6060 lb./hr (690 to 2700 lb./hr ft²). The middle diagram indicates the water distribution curve for one particular run (run R_3), and since air flow had little effect on the water distribution this curve is typical for most air rates under these conditions. The minima in the water distribution curve at the positions 2 and 15 were caused by the slat spacer rods which seemed to divert water away from these positions. The dotted line in this diagram indicates the theoretical or initial liquid distribution. The bottom diagram in Fig. 5 indicates the exit-air wet-bulb temperature traverse for the same run (R_3) as the water distribution curve. Measurements at points 1 and 16 were taken close to the tower walls, and there was evidently a colder air stream flowing in this region than in the rest of the packing.

It can be seen from Fig. 5 as a whole that, when water at 81°F was delivered uniformly to the tower, the exit water temperatures varied slightly across the packing. The gradual slope towards the right-hand side of the diagram was taken to indicate that the air flow was not quite uniform up to the tower, but it must be pointed out that this small deviation from uniformity would have been very difficult to detect by any method other than this.

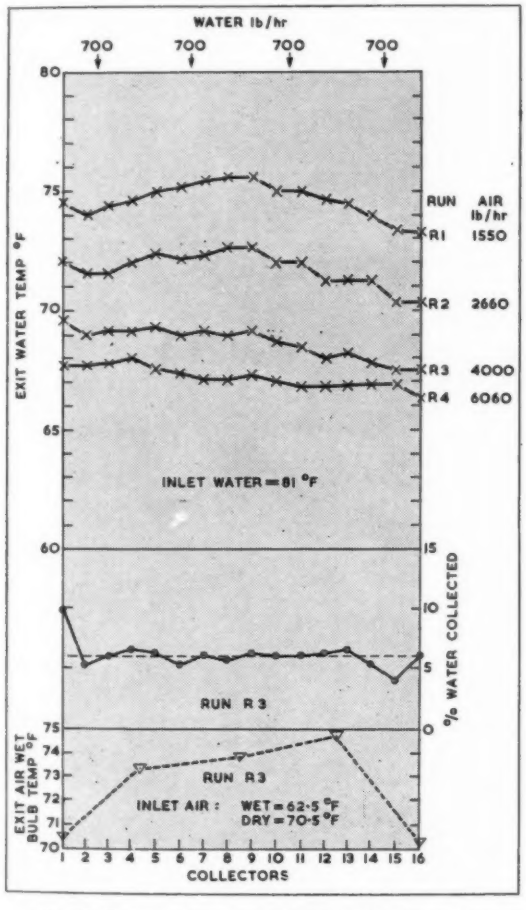

Fig. 5. Temperature and flow distribution when all four distributors deliver the same quantity of water (M = 1). The lower curve gives the wet-bulb temperature.

Fig. 6 shows the various traverses obtained when water was unevenly distributed over the top of the packing. In this case, distributors *A* and *B* delivered 1050 lb./hr each and distributors *C* and *D* delivered 550 lb./hr each, making a total of 3200 lb./hr (1420 lb./hr ft²) of water at 87°F under the conditions represented by maldistribution $M = 2$. The water flow distribution at the bottom of the tower exhibited a definite slope, but due to spreading within the packing the distribution ratio was not quite 2 : 1 at the point of collection. For the case illustrated (run R_7) 64.4% of the water was collected from the left-hand side of the tower and 35.6% from the right-hand side, giving a condition of maldistribution $M = 1.8$ at the bottom. The dotted line indicates the theoretical flow curve for maldistribution $M = 2$. The water temperature curves show pronounced slopes for the three air rates illustrated, and so does the exit air wet-bulb temperature curve for the inner portion of the packing. As reported for uniform water distribution (Fig. 5), the air temperatures were much lower close to the tower walls.

Fig. 7 illustrates the case of maldistribution $M = 3$. Distributors *A* and *B* delivered 1050 lb./hr each and distributors *C* and *D* delivered 350 lb./hr each, giving a total of 2800 lb./hr (1240 lb./hr ft²) of water at 85°F. The flow-rate distribution, as measured at the bottom of the tower, showed a more pronounced slope than the previous case, but again the maldistribution was less than the initial value. In run R_{10}, for instance, 68.5% of the total flow was collected from the eight left-hand troughs and 31.5% from the eight right-hand ones, i.e., a condition represented by maldistribution $M = 2.2$. It would appear, therefore, that any severe liquid maldistribution in a grid packing would soon smooth itself out. The temperature gradients for the three different air rates illustrated are steeper than those recorded in Fig. 6, and so is the wet-bulb temperature traverse. Lower air temperatures were again recorded close to the tower walls.

Performance Runs

It has been shown above how irregularities in the initial water distribution give rise to pronounced temperature gradients across the packing, and these conditions would be expected to have some effect on the overall efficiency of the tower. The experimental procedure was identical to that described for the temperature and flow traverses, but, in addition to the 16 exit-water temperature and flow measurements and the exit-air temperature traverse, two more measurements were required: the overall exit-water temperature and the overall exit-air wet- and dry-bulb temperatures. The former was obtained from a well-mixed sample of water collected simultaneously from the 16 troughs, and the latter was measured in an open cowl placed on top of the tower.

Methods for calculating coefficients of mass transfer for this type of operation have been described by a number of authors[4, 5, 6] and the procedure briefly is as follows. There are two transfer processes involved in a water-cooling operation: the transfer of latent heat of evaporation, and the transfer of sensible heat from the warm water to the air. The former process is usually predominant and accounts for about 80 to 90% of the total heat transferred. Taking these factors into consideration, the overall gas-transfer coefficient K_G (lb. mol/hr ft² atmos.) can be expressed as

$$K_G = \frac{G(i_{g_2} - i_{g_1})}{a\,Z\,p_{BM}\,M_B\,(i_i - i_g)\ mean} \qquad \ldots . (1)$$

where a = surface area of the packing per unit volume of tower (ft^2/ft^3);
Z = height of packing (ft);
p_{BM} = mean partial pressure of the air in the gas stream (atmos.);
M_B = molecular weight of air;
i_i = enthalpy of the air at the air/water interface (Btu/lb. dry air); and
i_g = enthalpy of the air in the main air stream (Btu/lb. dry air).

The value of the mean driving force in the tower $(i_i - i_g)$ *mean* is found by calculating the driving forces $(i_i - i_g)$ for three points in the tower: top, bottom and the "mean" point where 50% of the heat had been transferred. These three points are referred to by suffixes 1, 2 and m respectively. By the use of a chart (Fig. 8) due to Stevens and published by Carey and Williamson,[5] a factor f can be obtained which, when multiplied by the difference between the mean values of i_i and i_g, gives the required mean driving force:

$$(i_i - i_g)\ mean = f\,(i_{im} - i_{gm}) \qquad \ldots.(2)$$

The results may also be correlated on the basis of the number of overall gas phase transfer units N_{OG}, where

$$N_{OG} = \frac{i_{g2} - i_{g1}}{(i_i - i_g)\ mean} \qquad \ldots.(3)$$

and the height of a transfer unit is given by:

$$HTU_{OG} = \frac{Z}{N_{OG}} \qquad \ldots.(4)$$

When the heat lost by the water and the heat gained by the air did not balance exactly, the air flow was adjusted to correct the heat balance. Results giving errors larger than 10% were rejected. The method of calculation is illustrated below, using the data for one particular run:

Water rate, L	1240 lb./hr ft^2
Measured air rate, G'	1990 lb./hr ft^2
Water temperature (in)	78.7°F
Water temperature (out)	67.1°F
Air temperatures: (in) wet bulb ...	61.5°F
(in) dry bulb ...	69.9°F
(out) wet bulb ...	71.2°F
(out) dry bulb ...	71.7°F
Packed height, Z	2.71 ft
Specific surface, a	19.7 ft^2/ft^3

Water Evaporated.

Exit air humidity	= 0.0164 lb. water/lb. dry air
Inlet air humidity	= 0.0098 lb. water/lb. dry air
Humidity gain	= 0.0066 lb. water/lb. dry air
Water evaporated	= 1990 × 0.0066
	= 13 lb./hr ft^2

Heat Balance

Exit air enthalpy, i_{g2} ...	= 27.60 Btu/lb. dry air
Inlet air enthalpy, i_{g1} ...	= 19.87 Btu/lb. dry air
$i_{g2} - i_{g1}$	= 7.73 Btu/lb. dry air
Heat gained by air, Q_A	= 1990 × 7.73
	= 15,380 Btu/hr $ft.^2$
Heat lost by water, Q_W	= (1240 × 78.7) − (1227 × 67.1)
	= 15,060 Btu/hr ft^2

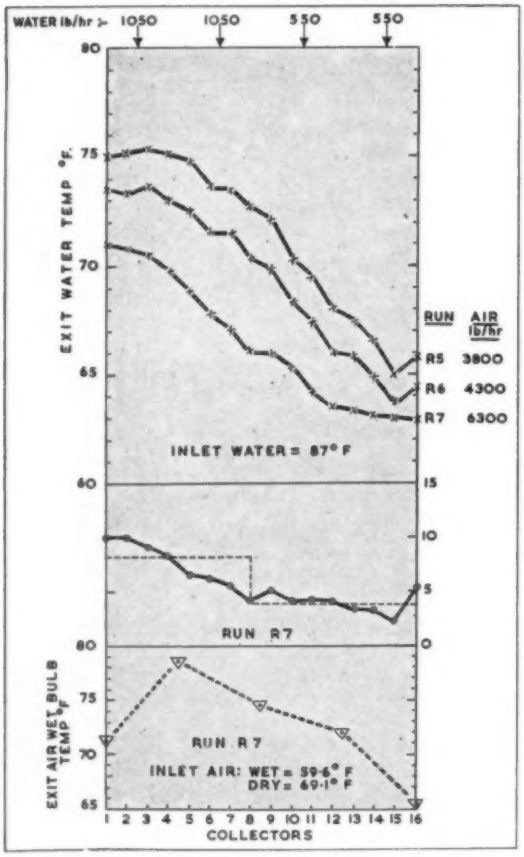

Fig. 6. Result of uneven distribution of water across the top of the packing for maldistribution (M = 2.0).

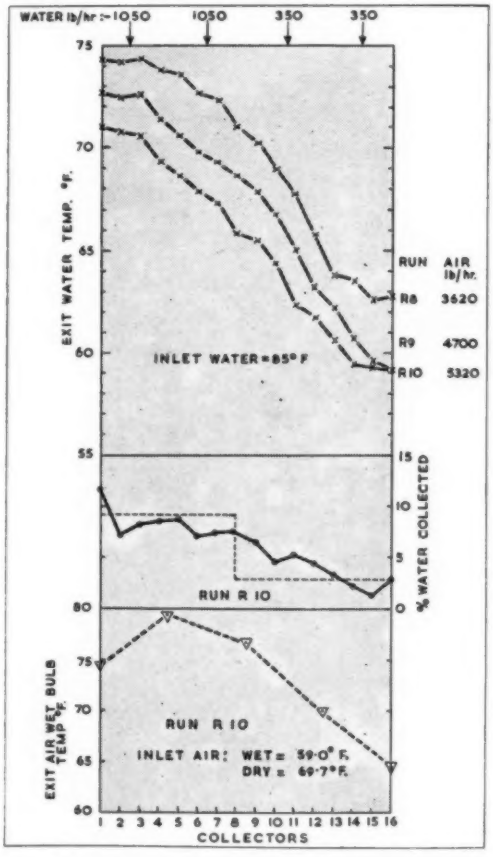

Fig. 7. Effect of uneven distribution of liquid (M = 3) at the distributors upon the liquid distribution in the column.

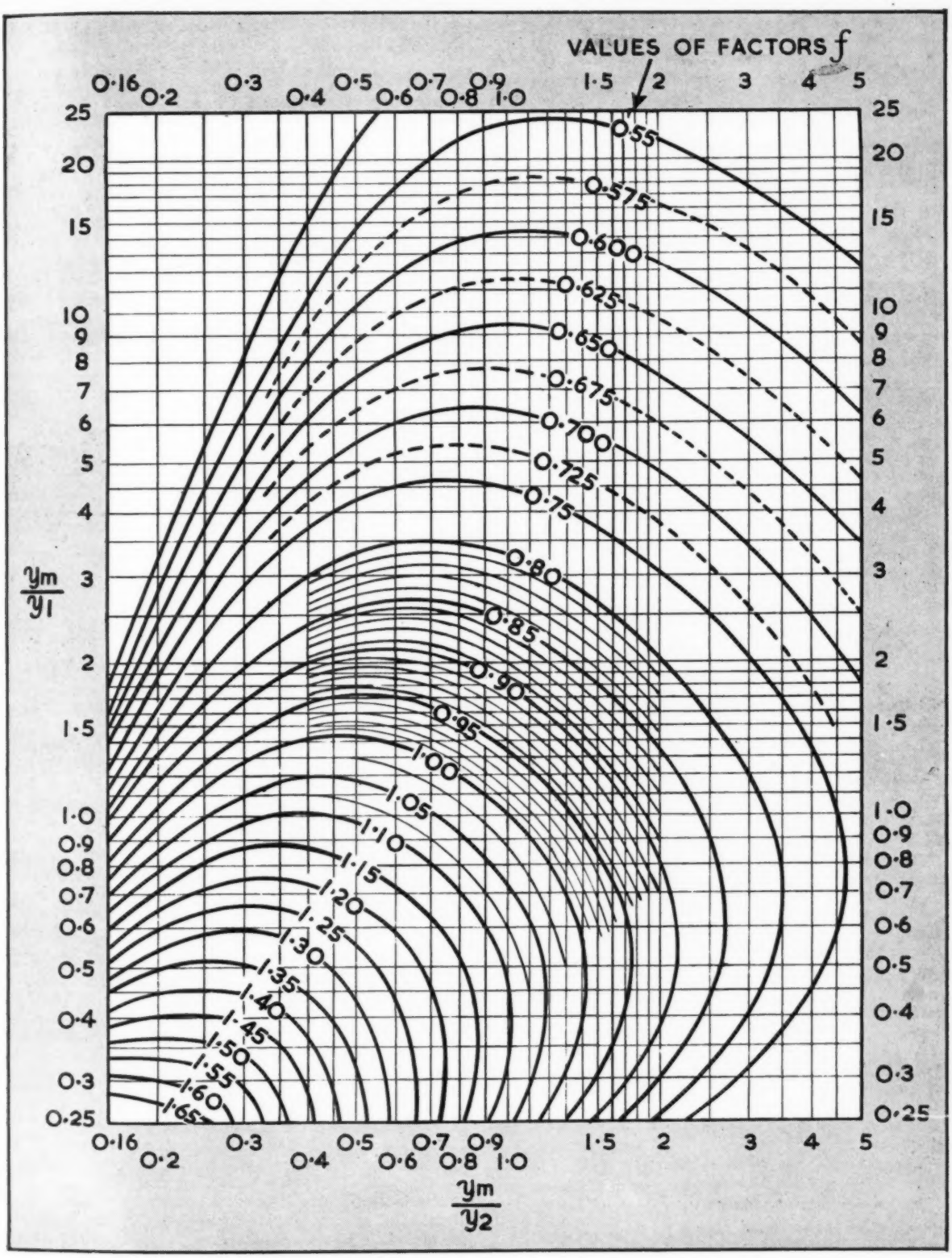

Fig. 8. Chart for determining factor f *used in estimating mean enthalpy driving force.* y_m *is the driving force at the "mean" point* $(i_{im} - i_{gm})$, y_1 *and* y_2 *are the driving forces* $(i_i - i_g)$ $(i_{i2} - i_{g2})$ *at the bottom and top of the column respectively. This chart was devised by W. L. Stevens and published in the work of Carey and Williamson (see Reference 2).*

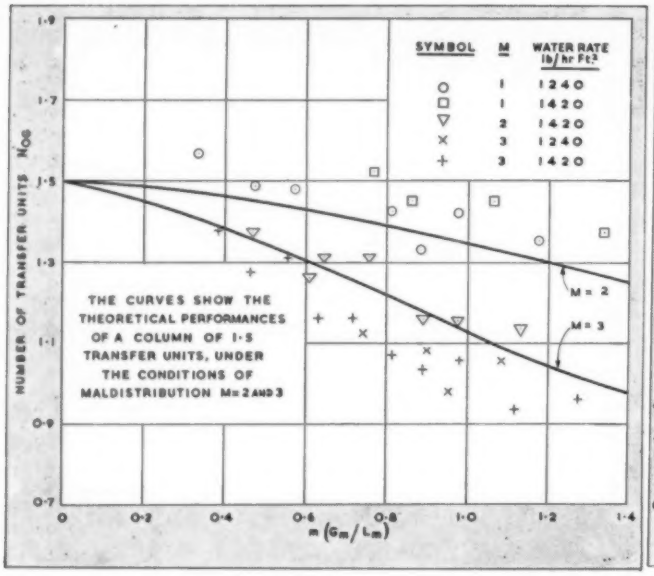

Fig. 9. Relation between overall gas transfer coefficient K_g *and air rate* G.

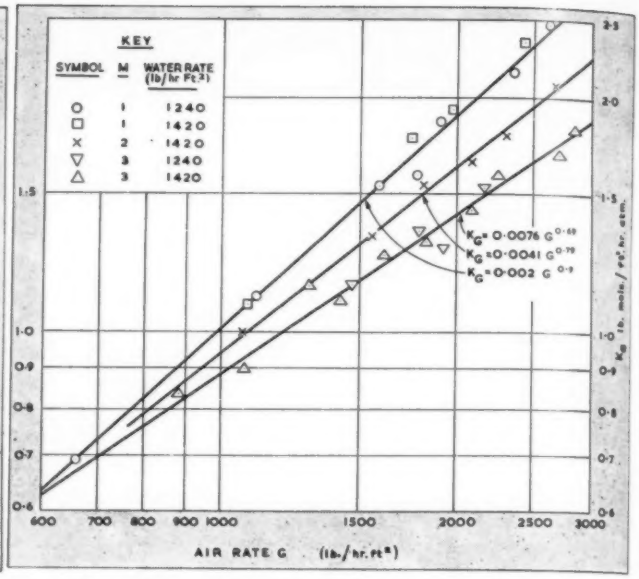

Fig. 10. Variation of number of transfer units N_{OG} *with the product of the operating line slope* m *and* G_m/L_m.

100 Q_W/Q_A ... ... = 98%
Corrected air rate, G ... = 1950 lb./hr ft²

Enthalpy Differences

	Top (2)	*Bottom* (1)	*Mean* (*m*)
Water temperature (°F)	78.7	67.1	72.9
i_i (Btu/lb.)	34.90	24.20	29.19
i_g (Btu/lb.)	27.60	19.87	23.73
$(i_i - i_g)$ ...	7.30	4.33	5.46

The value of the factor f can be found from Fig. 8, where y_n denotes the driving force at the "mean" point $(i_{im} - i_{gm})$, and y and y_2 denote the driving forces at the bottom and top of the tower $(i_{i1} - i_{g1})$ and $(i_{i2} - i_{g2})$ respectively. Thus, $f = 0.995$.

So, using Equation (2) $(i_i - i_g)$ *mean* $= 0.995 \times 5.46$
$= 5.45$ Btu/lb.

Then the number of transfer units is given by Equation (3):

$$N_{OG} = \frac{27.60 - 19.87}{5.45} = 1.42.$$

To calculate the value of the overall mass-transfer coefficient, K_G, a value of p_{BM} is required for use in Equation (1). This is taken as the arithmetic mean of the partial pressures of air in the body of the gas and at the air/water interface at the top and bottom of the tower:

Top	*Millibars*
Partial pressure in body of gas	= 25.74
Partial pressure at interface	= 34.90
Mean partial pressure	= 30.32
Bottom	
Partial pressure in body of gas	= 15.53
Partial pressure at interface	= 22.68
Mean partial pressure	= 19.10
Mean of top and bottom means	= 24.71
	= 18.55 mm. Hg.

$$So\ p_{MB} = \frac{760 - 18.55}{760} = 0.975 \text{ atmos.}$$

Then from Equations (1) and (3):

$$K_G = \frac{G}{a\ Z\ p_{BM}\ M_B} \times N_{OG}$$

$$= \frac{1950 \times 1.42}{19.7 \times 2.71 \times 0.975 \times 9}$$

$$= 1.84 \text{ lb. mol./hr ft.}^2 \text{ atmos.}$$

Two water rates (1240 and 1420 lb./hr ft²) and air rates ranging from about 700 to 2800 lb./hr ft² were employed in the experimental work. Inlet water temperatures were kept constant for each run in the range 80° to 90°F. Fig. 9 shows how the results calculated on the basis of the overall gas transfer coefficient, K_G, varied with the air rate G. When the water distribution was uniform ($M = 1$), the results could be correlated by the formula

$$K_G = 0.002\ G^{0.90}$$

There was no significant difference between the results obtained with a water rate of 1240 lb./hr ft² and those obtained with a rate of 1420 lb./hr ft². When water was deliberately maldistributed in the ratio of 2 : 1 (total water rate 1420 lb./hr ft²) the results could be correlated by the formula

$$K_G = 0.0041\ G^{0.79},$$

and when the water maldistribution was 3 : 1 (total water rates of both 1240 and 1420 lb/hr ft²), the correlation was

$$K_G = 0.0076\ G^{0.69}.$$

The value of the exponent of the air rate, G, is therefore dependent upon the degree of liquid maldistribution; it varied from 0.9 for uniform water distribution to 0.69 when water was initially maldistributed in the ratio of 3 : 1. These results may also be correlated on the basis of the number of overall gas-transfer units, N_{OG}, and it was indicated in Fig. 2 how the performance of a column would be expected to fall, theoretically, under certain conditions of liquid maldistribution. Fig. 10 shows how the number of transfer units, N_{OG}, varied with the group $m\ (G_m/L_m)$, where m is the slope of the operating line and G_m/L_m is the molar gas : liquid ratio.

For uniform water distribution ($M=1$), the value of N_{OG} was about 1.5 over the range $m\ (G_m/L_m)$ 0.5 to 0.8.

Over the range m (G_m/L_m) 0.8 to 1.4, the value of N_{OG} fell gradually to about 1.4. For maldistribution $M = 2$, the value of N_{OG} fell from about 1.4 to 1.15 over the range m (G_m/L_m) 0.4 to 1.2. For maldistribution $M = 3$, N_{OG} fell from about 1.4 to 0.95 over the range m (G_m/L_m) 0.4 to 1.3. It is clear, therefore, that the greater the degree of liquid maldistribution the greater is the decrease in performance.

The two curves in Fig. 10 represent the theoretical deteriorations in performance of a column with an original value of $1\frac{1}{2}$ transfer units (c.f. Fig. 2). It will be noted that the results are not fitted very well; for instance, the results obtained for a water maldistribution of $M = 2$, are best fitted by the theoretical $M = 3$ line, but it is impossible to predict the exact initial value of N_{OG} and the value of $1\frac{1}{2}$ is chosen here purely for illustrative purposes. However, it does appear that the results for uniform distribution would best be fitted by a line representing the effect of something like maldistribution $M = 1.5$ on a tower having $1\frac{1}{2}$ transfer units.

A number of explanations are possible. First, as mentioned above, slight exit-water temperature gradients were recorded across the bottom of the tower, even though the water distribution was uniform (see run R_1, Fig. 5) and this was taken to indicate a slight maldistribution of air up to the packing. Secondly, each grid had a $\frac{1}{4}$-in. clearance from the tower walls on two sides, and a $1\frac{1}{4}$-in. clearance on the other two; this arrangement was followed alternately down the tower. During the water-cooling runs, a cool air stream flowed up the sides of the tower (see run R_5, Fig. 5) and this air was obviously not being utilised to its fullest extent.

Subsequent investigation showed that the air velocity in the $1\frac{1}{4}$-in region around the wall was about 10% higher than in the rest of the packing. This result was understandable because the free space in the wall region was 95% compared with 87% for the bulk of the packing. As the above region constituted about 20% of the cross-sectional area of the tower, the gas : liquid ratio here was higher than in the rest of the packing. Furthermore, due to the cut-away ends of the slats in the grids, the surface area available for flowing water was reduced. Therefore, in 20% of the tower another form of maldistribution existed, and, from the results of the uniform water distribution runs, it seems that this was equivalent to about $M = +0.5$.

Flow Rate and Packing Performance

This additional maldistribution should have constituted a constant factor in all the water-cooling runs, but it is still not sufficient to account for the results of maldistribution $M = 2$ being fitted by the theoretical $M = 3$ line. It is even more surprising in view of the fact that it has been shown that any initial liquid maldistribution tends to smooth itself out as the liquid proceeds down the tower (see Figs. 6 and 7). One feature which probably accounts for this anomaly is the underwetting of the packing surfaces when the liquid rate is reduced down one side of the tower.

The only guide to the effect of liquid flow rate on the performance of a packing is the minimum effective liquid rate (MELR)[6, 7]; when the liquid rate falls below the MELR, the performance of a packing is liable to deteriorate rapidly. The value of the MELR for $\frac{1}{4}$-in thick grids pitched at 1 in. is about 1300 lb./hr ft^2, so the overall water rates of 1240 and 1420 lb./hr ft^2 used in the experimental work can be considered sufficient for efficient operation.

However, when water was maldistributed in the tower, one section carried rates in excess of the MELR while the other section carried rates much less than the MELR. For example, in one typical run (run R^{10}, Fig. 7) the total water rate was 1240 lb./hr ft^2, but under the conditions represented by maldistribution $M = 3$ the quantities of water entering the two halves of the tower were 1870 and 620 lb./hr ft^2 respectively, while the quantities leaving the tower were 1700 and 785 lb./hr ft^2. So throughout one half of the packing the liquid rate was well below the MELR, a condition which would cause a reduction in the overall performance. This reduction would be additional to the effect of maldistribution.

Conclusions

It has been shown how the performance of a grid-packed tower deteriorates under known conditions of liquid maldistribution. The exponent n of the gas rate G in the mass-transfer equation $K_G \propto G^n$ varied from 0.9 for "uniform" distribution to 0.69 for a severe maldistribution. It would appear, therefore, that high values of n for gas-film-controlled processes would afford some indication of the uniformity of liquid flow.

Maldistribution in tower packings is detrimental to performance, and it should be eliminated as far as possible. Due to the regular constructional arrangement of a grid-packed tower, most of the dangers of maldistribution can be avoided to a large extent, and the maximum efficiency of a grid packing, whether it be used in a water cooler, absorption tower or distillation column, will be approached when the liquid and gas distribution are uniform, and when the operating value of the group m (G_m/L_m) is as low as possible, preferably less than unity. This latter condition, of course, cannot always be obtained, as it is governed by the operating system and the required duty, but even slight degrees of maldistribution will become evident in the form of poor performance at high values of m (G_m/L_m).

Fairly uniform liquid distribution in an accurately assembled grid packing can be obtained quite easily, and suitable trough distributors have been described by a number of authors[5, 6]. Uniform gas distribution probably presents fewer difficulties in grid packings than in random packings, but of course care must be taken. It has been indicated, however, that an excess of gas flow can occur in the peripheral region of a grid tower due to the slightly greater free space, and should this small degree of gas maldistribution become serious, steps could be taken to reduce it by the use of suitably designed baffles.

Grid packings offer many advantages over some of the more commonly used packing materials. Apart from the ease with which fairly uniform liquid and gas distributions can be achieved, with a corresponding benefit to performance, the pressure drops through these open-structure grids are relatively small. Grids can be fabricated from a number of materials, such as wood, porous ceramics, carbon and mild steel, but it is important to remember that the grids must be easily wetted by the liquid being used. The wetting properties of mild steel, for instance, depend upon the condition of its surface: the rusty metal is easily wetted, but the polished metal has a very poor wettability. In view of their many desirable properties, it is surprising that grid packings are not more widely used in gas-liquid contact operations.

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LIQUID ATOMISATION IN CHEMICAL ENGINEERING: PART 4.* TWIN-FLUID ATOMISERS

In this, the last section of their article on liquid atomisation, the authors deal with twin-fluid atomisers and their operating principles

by R. P. FRASER, O.B.E. M.I.Chem.E., P. EISENKLAM, Ph.D., M.Eng.Sc., and N. DOMBROWSKI, Ph.D., A.M.I.Chem.E.

LIQUID atomisation by means of a gaseous medium is sometimes referred to as pneumatic atomisation and, in the liquid fuel industry, as blast atomisation. Needless to say, any gaseous fluid can be used for the purpose. For example, it is practicable to atomise a non-inflammable liquid fuel by means of carbon dioxide and obtain perfectly satisfactory combustion, and under certain conditions in chemical plant it may be convenient to utilise a gas such as hydrogen, or inert gas, to prevent oxidation of the dispersed phase.

Whereas in pressure atomisation the energy is contained within the liquid itself, the amount of energy available for atomisation in twin-fluid atomisers can be much greater and independent of the fuel quantity. With the pressure nozzle, there is a limitation of drop size with discharge rate and, also, the turn-down ratio is small and the spray angle more limited. With blast atomisers very wide spray angles can be obtained and the small drop size can be achieved with large flow rates.

In combustion engineering it has been common practice to divide the twin-fluid atomiser into three groups, according to the gas pressure and volume supplied to the atomiser per lb. of liquid. The low pressure group operates between 150 and 380 ft/sec. gas velocity (5 to 35 in. wg). The intermediate group between 500 and 850 ft/sec. (1.5 to 10 lb./sq. in.), and the high velocity group with sonic or supersonic velocity (14 lb./sq. in. upwards). This division is related to the method of providing the gaseous medium by either fan, rotary blower or reciprocating compressor, respectively.

They may also be classified into internal and external mixers according to whether the gas and liquid meet internally within the body of the atomiser or outside in the atmosphere. In the first class, the fluid pressures interact upon each other and, therefore, an adjustment of the flow of one affects the flow of the other. This makes control somewhat more complex. In the second class the fluids can be adjusted independently, and thus the air-liquid mass ratio can be changed by reducing the flow of the liquid only. A number of different designs are shown in Figs. 1, 4 and 5.

It is surprising how little of the fundamental principles of disintegration of a liquid in a gas stream has been applied to the great number of designs of twin-fluid atomisers which have been made during the last century. Their mechanical efficiency is still extremely low and there is an increasing demand for atomisers of greater energy transfer.

Process of Drop Formation

In principle, the method of atomisation depends upon the high shearing forces caused by friction between the liquid surface and a gas travelling at a high relative velocity. The gas, in fact, may be expanded from a pressure and temperature to obtain supersonic velocity in the nozzle before meeting the liquid, and may also be made to rotate rapidly in a vortex existing outside in the atmosphere or internally in a vortex tube.

A number of investigations by means of microsecond photography has shown that the manner of disintegration is the same as with pressure nozzles, in that ligaments or threads of liquid are first formed by air friction which

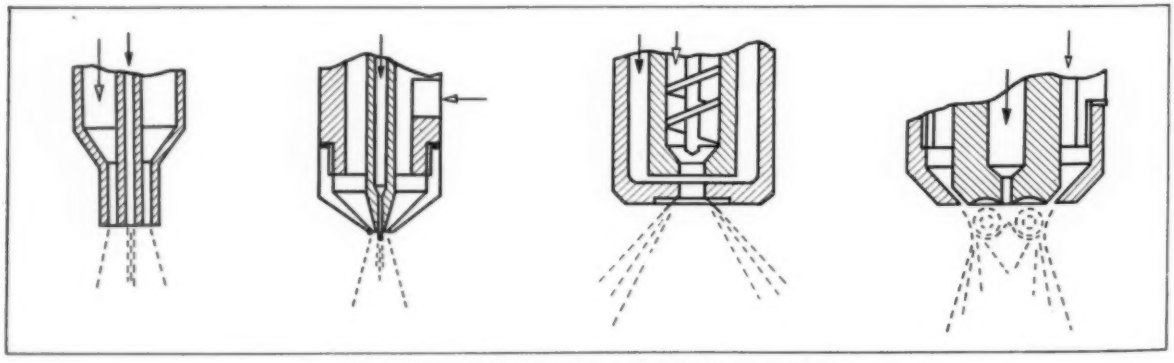


Fig. 1. Characteristic designs of twin-fluid atomisers.

* *This section (Part 4) concludes the series. Previous parts were published in the August, September and October issues.*

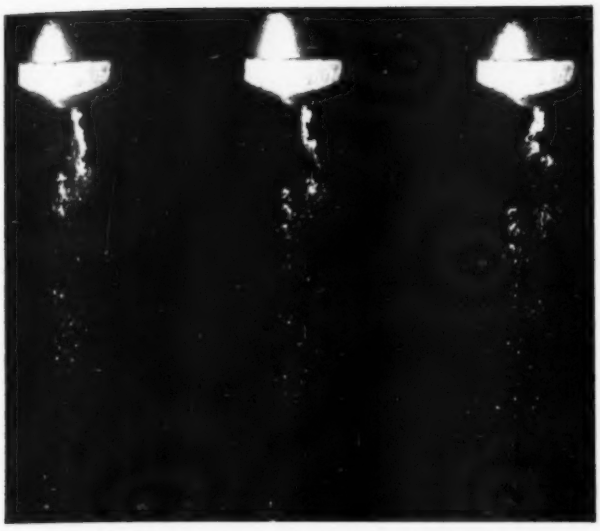


Fig. 2. Three successive instants in the disintegration of a cylindrical liquid jet in an annulus of low-velocity air (0.3 millisec. interval).

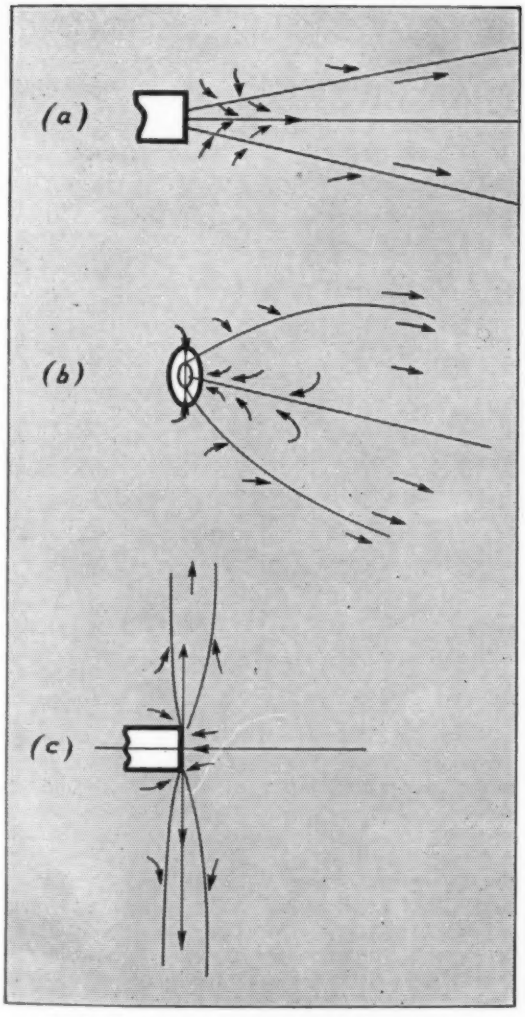


Fig. 3. Shape of spray and entrainment of air into the air blast.

then break down into drops. When, however, the difference of velocity between gas and liquid is very high and finer atomisation results, it becomes more important to ensure contact between the liquid and gas stream. When the gas velocity is sonic or supersonic there is sometimes a marked improvement in atomisation and the effect of shock waves in the gas stream must not be ignored.

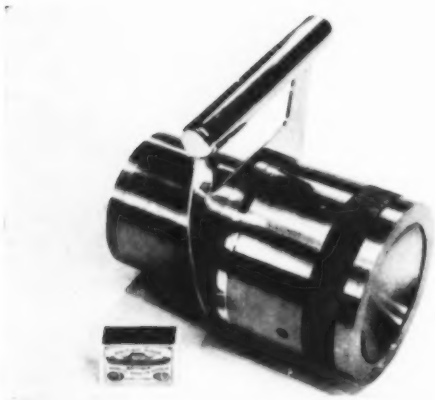
It has been observed that when large single drops are exposed to a steady air stream, the drops are first blown into a film shaped as a bag which then collapses like a bubble. This bubble leaves a ring of drops where the edge of the bag existed. When drops have been reduced by this process to a critical size, they will not break up further, and this fact is of importance with regard to drops passing into a high-velocity gas stream. At relative sonic velocity this critical size, for water, is approximately 5μ, although larger drops have been observed to survive.

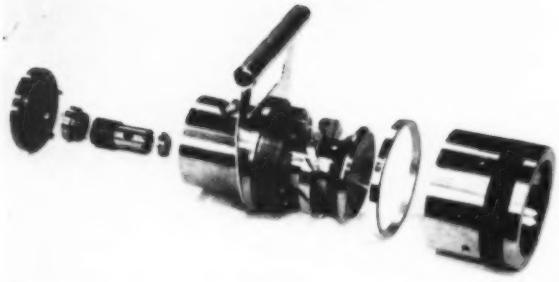
Twin-fluid atomisation is, so far, the only successful method of producing very small particles where the mean drop diameter is below 20μ. Drops of aerosol dimensions can be produced as the result of break-down of the very thin films into very fine threads. Under high-sheer conditions the life of such threads is very short—of the order of 0.0001 to 0.0003 sec. for diameters under 10μ. According to some observers it would appear that drops can be torn directly from the body of the liquid, but this is probably due to the limitations in photographic technique.

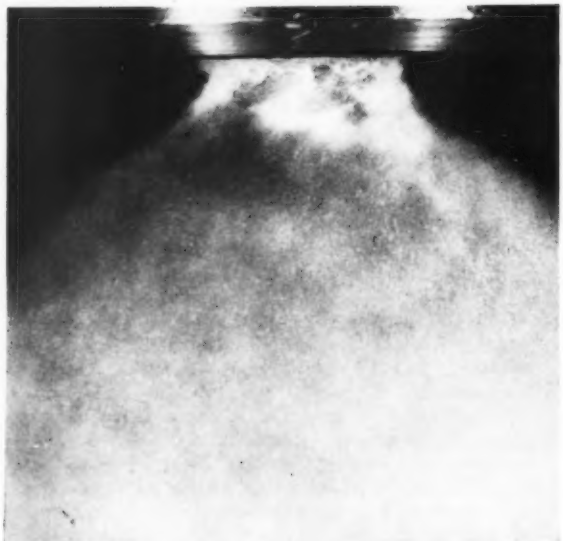
When a small diameter jet of liquid of low relative velocity is ejected coaxially into an air stream of velocity above 100 ft/sec., the liquid jet is violently disturbed and becomes pinched off periodically into masses of liquid which are blown apart as they distort under acceleration (Fig. 2). A wide spectrum of drops is produced and the spatial dispersion of the drops is poor, a high concentration remaining upon the jet axis.

The earliest recorded atomiser of this type was devised in 1866 and it is still typical of many of those used today, particularly for small throughputs where an annulus of high velocity air or steam surrounds a solid jet of liquid. When the required liquid throughput is high, and the liquid jet diameter thus becomes large, the efficiency of applying the energy in this way is diminished. It is inefficient because, firstly, the gas stream impinges upon a solid jet of liquid of large diameter and, secondly, the direction of the air is the same as that of the liquid. The gas quickly accelerates the liquid particles to its own velocity, and little further shear can occur. One method of overcoming this difficulty with atomisers of large throughput is to arrange that the liquid will be filmed into a thin sheet before meeting the high-velocity air stream. There are a number of ways of doing this. The liquid may be caused to form a sheet by passing it through a pressure nozzle as the first stage, to produce either a conical film from a swirl spray nozzle, or by a flat sheet from a fan spray nozzle.

When the prefilming method is applied it is found that atomisers of large throughput can have nearly as small a mean-drop size for the same gas/liquid mass ratio as the smaller size atomisers. Such atomisers have a very large turn-down ratio and, moreover, in certain designs the mean drop size is found to change very little as the quantity of liquid is reduced for a given air mass flow in a given size atomiser. This condition is advantageous where the same drop size is required over a range of throughputs. A design typical of this type is shown in Fig. 4 where the exploded view shows the swirl spray nozzle component in the centre of a vortex cup. Fig. 5 shows a low-pressure type where the atomising gas and the liquid can be metred simultaneously by linking the movement of a V notch liquid valve with an adjustable air annulus. When liquid is disintegrated by a gaseous jet having a high component of forward velocity and the gas velocity is high, there is







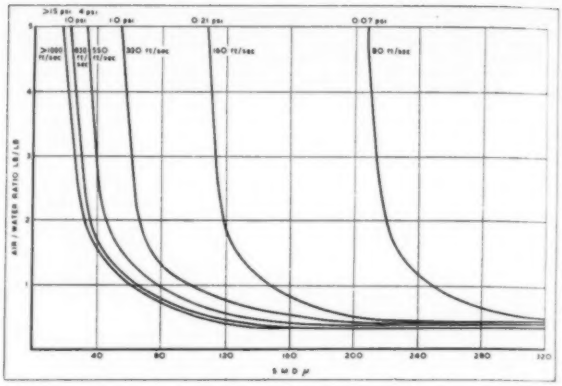


Fig. 4 (left). Typical medium-pressure vortex cup atomiser: (a) external view; and (b) exploded and showing internal swirl spray pressure nozzle. Fig. 5 (middle). Typical low-pressure proportioning atomiser showing liquid control valve and air annulus inter-

considerable momentum in the spray and expanding gas column. The spray, therefore, will penetrate to a greater distance than from a pressure nozzle (Fig. 3(a)). However, many practical designs arrange that a part or all of the high-velocity gas stream is rapidly rotating around the nozzle axis so that the spray angle may be increased and the forward momentum reduced. In some designs spray angles greater than 90 degrees and even up to 180 degrees can be obtained in this manner (Fig. 3(b) and (c) and Fig. 6). This vortical motion to obtain wide-spray angles also induces a recirculation of air towards the nozzle mouth (Fig. 3(b) and (c)) together with extremely rapid entrainment of air from outside the spray cone towards the axis. Thus vortex atomisers are good mixers.

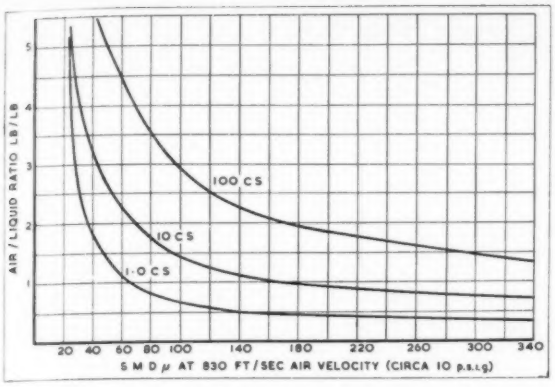
Drop Size from Twin-Fluid Atomisers

The effects of liquid physical properties on drop size from twin-fluid atomisers are not yet well established. Experimental work with small blast nozzles of the internal mixing type operating with high volumetric air/liquid ratios led to the development of the following formula applicable within the range of liquid physical properties given:

$$SMD = \frac{585}{V}\sqrt{\frac{\gamma}{\rho_L}} + 597\left(\frac{\eta_l}{\sqrt{\gamma\rho_L}}\right)^{0.45}\left(\frac{1000}{j}\right)^{1.5}$$

where V = velocity of air relative to liquid m/sec. (subsonic to sonic at nozzle exit);
γ = surface tension dynes/cm. Range 30 −73 ;
ρ_L = liquid density g/cm³. Range 0.8 − 1.2;
η = absolute viscosity poise. Range 0.01− 0.3;
j = actual air/liquid volume ratio at air and liquid orifice respectively; i.e. at pressure of surrounding atmosphere.

This relation indicates that the Sauter mean drop size is determined by the amount of air per unit of liquid and the relative fluid speeds. Thus drop size is reduced as the air pressure and the air/liquid weight ratio is raised. The formula also shows that to obtain a surface mean diameter below 20μ, air velocities greater than 700 ft/sec. and air/liquid weight ratios above 10 lb./lb. may have to be employed. Fig. 7 illustrates the relation of air/liquid weight ratio to mean drop size for variations of gas velocity. It is observed that considerable atomisation is achieved with relatively low-air pressures, less than 1 lb./sq. in.g. But to achieve drop sizes with water below 80μ requires increasing quantities of air and, also, a greatly increased velocity



connected. Fig. 6 (bottom). Vortex cup atomiser operating at 14 lb./sq. in. Fig. 7 (above left). Relation of air/liquid ratio and drop size for various gas velocities. Fig. 8 (above). Relation of drop size mass ratio at different viscosities.

difference. The effect of increasing viscosity utilising the same formula is shown in Fig. 8, where each curve is for a velocity of 830 ft/sec., corresponding approximately to 10 lb./sq. in.g. The viscosities are 1 cs., 10 cs., and 100 cs., with a surface tension of 28 dynes/cm., compared with water 1 cs. and 73 dynes/cm. The marked effect of increased viscosity with the same gas velocity is observed.

Fig. 9 represents a correlation of the majority of known drop size determinations with atomisers of various designs, excluding those of the simple injection type. The band represents viscosities up to 40 cs. and mass flows up to 500 lb./hr with air pressures of 10 to 50 lb./sq. in.g. It is observed that these results, with modern designs of atomisers of both the internal and external mixing type, realise an improvement over the predicted performance of injection nozzles as given in Figs. 7 and 8. Nevertheless, a very large mass flow of air is required at a pressure above 15 lb./sq. in. to achieve mean drop sizes of 20μ or below.

Where the liquid mass flow is very small and the gas velocity can be sonic or greater, a mean drop size less than 10μ may be obtained with a gas/liquid ratio of 3 or more, and this appears to be possible regardless of design. Where the liquid flow rate is high, however, and small drops are desired, the design of the atomiser becomes important, for it is necessary to ensure that the liquid is prefilmed and the contact of the liquid and gas are made more efficient.

The application of twin-fluid atomisers to spray driers is not yet common. However, where small particle sizes are required, they are more suitable than other types, but the large amount of gaseous fluid usually required tends to limit their use to small liquid throughputs. The possibilities of drying and producing small particles without the necessity of further grinding are attractive; that smaller drop sizes can be obtained from liquids having higher viscosities than with pressure nozzles is also an advantage.

The rate at which the energy has to be increased to reduce the drop size below 100μ can be seen in Fig. 10. This figure is a plot of the kinetic energy in a simple unidirectional air jet expanding isentropically from an orifice, such as in a simple injection atomiser giving a flow pattern as represented in Fig. 3(a). It is observed in Fig. 10 that a mean drop size of 110μ at an air/liquid ratio of 1 lb./lb. can be obtained with an expenditure of only 100 ft lb., but to achieve a drop size of 50μ requires well over 20,000 ft lb. At low velocities of a few inches water gauge the expansion of the gas may be partly isothermal so that the energy in the jet would be higher.

It is common practice with commercial atomisers to operate between about $\frac{1}{4}$ and 10 lb./sq. in.g. and for the

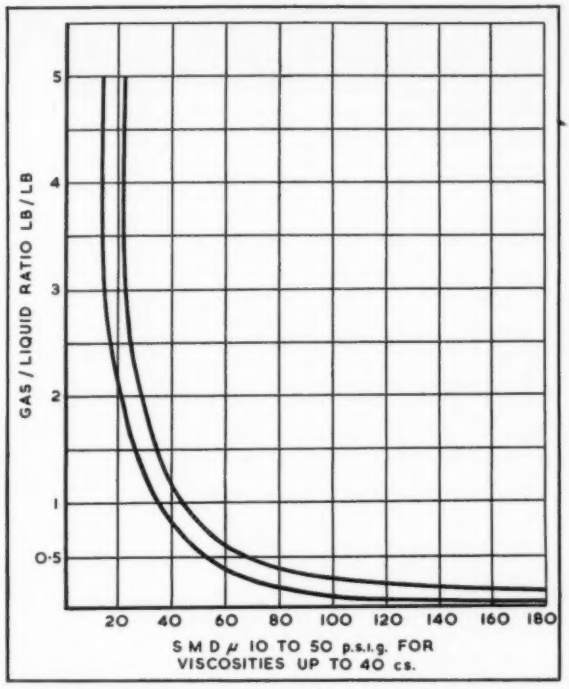


Fig. 9. Drop size correlation for twin-fluid atomisers.

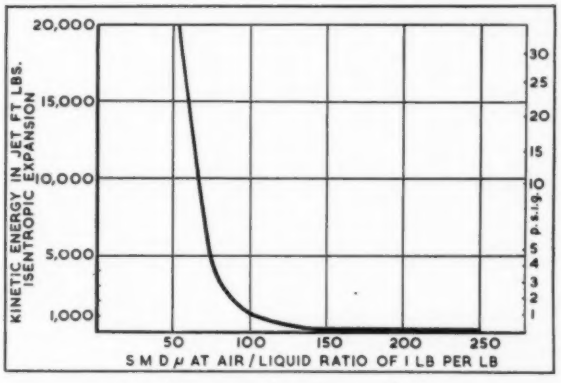


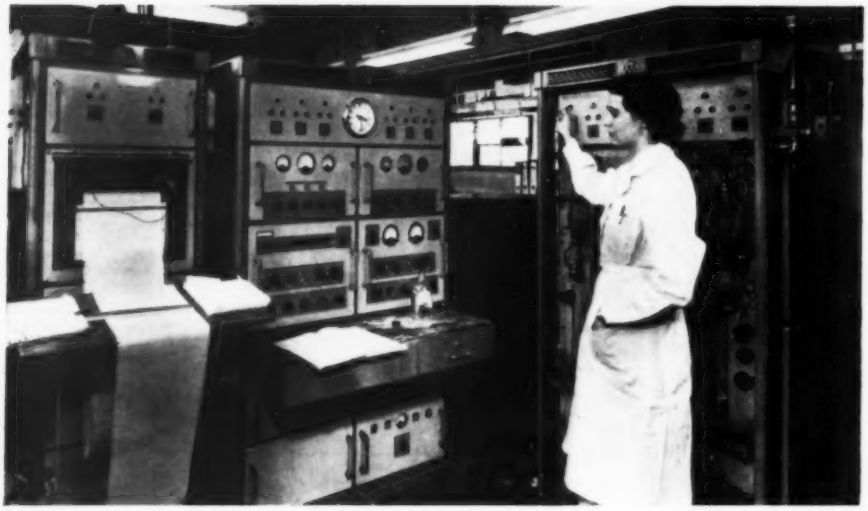
Fig. 10. Drop size energy relation.

smallest drop size to use pressures between 15 and 20 lb./sq. in.g. to obtain sonic velocity. Practically no atomisers have, so far, been designed to effectively employ velocities of Mach 3 or more, corresponding to the proper isentropic expansion of a gas at high pressures. Much more research is still required, however, to improve the efficiency of energy transfer and to devise types of blast atomiser capable of handling large throughputs economically. Larger atomisers for gas reactors have been designed for as much as 15 tons an hour but, at present, with the efficiency of disintegration of only a fraction of 1%, such an atomiser reducing 15 tons/hr to a mean drop size less than 40μ requires energy equivalent to a steam consumption of at least 10 tons/hr at 100 lb./sq. in.

ACKNOWLEDGMENTS and ERRATA

Fig. 11 in Part 2 (September issue, p. 397) was reproduced from Proc. Phys. Soc., *62B (1949), 23, by kind permission of the authors. Equations (16) and (17) in Part 3 (October issue, p. 543) were derived from results obtained at the Fire Research Station; see F.C. Note No. 49/1951 and F.R. Note No. 181/1955 respectively. Fig. 4 is here reproduced by permission of Urquhart's (1926) Ltd., and Fig. 5 by permission of the Nu-Way Heating Plant Co. Ltd.*

In Table 2, p. 416 of Part 1, August issue, "9. Solid cone spray" should have read as "Drowned cone spray." The captions of Figs. 2 and 3 were transposed in Part 3 (p. 538), October issue.



An industrial mass spectrometer in use at Shell's Stanlow refinery. The operator is introducing a liquid sample for analysis.

THE MASS SPECTROMETER IN THE CHEMICAL INDUSTRY

by G. N. ROSS, B.Sc.

This article shows how the mass spectrometer compares as an analytical tool with other physical and chemical analytical techniques

ALTHOUGH a few mass spectrometers and spectrographs had been used in universities for the study of isotopes and for the precise measurement of atomic masses, it was not until the outbreak of the Second World War and the rapid development of atomic energy projects that large numbers of mass spectrometers were required. Initially, this demand stemmed from the need for instruments to measure isotope abundances on very small samples, problems ideally suited to solution by mass spectrometry, and there are now many machines in use for this purpose. However, these developments follow classical lines and greater interest is being shown in the development of mass spectrometric analytical techniques in the petroleum and chemical industries, where instruments are now in daily routine use on quantitative and qualitative analytical problems. So rapid has been the development in these latter techniques that it is impossible here to deal adequately with all the applications. Furthermore, it would be of little advantage when one considers that there are now several excellent books on mass spectrometry[1] containing many detailed accounts of individual applications.

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Principles of Mass Spectrometry

Essentially, a mass spectrometer or spectrograph performs three functions. First, ions are formed from the sample under study; secondly, these ions are sorted according to their masses by suitably disposed electric and magnetic fields; and, thirdly, the relative numbers of ions formed at each mass are counted or recorded. These functions may perhaps be understood best by reference to Figs. 1 and 2, which illustrate diagrammatically a simple instrument, a simple analytical problem (the analysis of a mixture of nitrogen and oxygen), the functions of each of the essential units and the display normally printed by the recording system. For the complete assay of the particular mixture chosen to illustrate the analytical technique, it would be essential to calibrate the spectrometer with standard charges of oxygen and nitrogen so that the sensitivities of the instrument (i.e., ion beam intensities per unit sample charge) for each component were known.

As can be inferred from the illustration, the ionisation chamber is the most important component of the mass spectrometer. In most instances the material under study is introduced into this chamber as a gas or vapour from a sample reservoir of 1 to 5 litres in capacity. Normally

the gas flows continuously during analysis, the constants of the flow system being chosen so that the pressure in the ionisation chamber (10^{-4} to 10^{-6} mm) remains constant during the recording of the spectrum, and the mixture in the chamber is representative of the sample at all times. Inside the chamber the material is bombarded with a stream of electrons of closely-controlled energy within the range 50 to 70 eV. Under these conditions some of the molecules are ionised with the loss of one or more electrons, some fragment ions are produced and some ions are formed with the addition of an electron. The number of negative ions and particles with more than one charge that are formed are very small compared with the yield of singly-charged positive ions. Even so, where molecules of the material under study contain a large number of atoms, the spectrum obtained is very complex, as can be seen from the *n*-butane spectrum shown in Fig. 3. However, under fixed ionising conditions every compound has its own characteristic mass spectrum and this fact has enabled the instrument to be employed successfully for the analysis

TABLE 1—TYPICAL MASS SPECTROMETER ANALYSIS

Component	Mass Spectrometer Analysis in Mol. %
Hydrogen	20.3 ± 0.60
Methane	12.6 ± 0.50
Ethylene	4.2 ± 0.60
Ethane	5.0 ± 0.50
Propylene	3.8 ± 0.30
Propane	4.2 ± 0.40
Isobutylene	6.5 ± 0.70
Total *n*-butylenes	3.9 ± 0.80
Isobutane	8.2 ± 0.50
n-butane	7.6 ± 0.50
Total pentylenes	0.2 ± 0.05
Isopentane	0.3 ± 0.05
n-pentane	0.2 ± 0.05
Carbon dioxide	22.7 ± 0.50
Carbon monoxide + nitrogen	10.2 ± 0.70
Total C_6 compounds	0.1 ± 0.05
Total butylenes	10.4 ± 0.40

of multi-component mixtures containing components whose spectra overlap considerably. The full scope of the instrument in this connection may perhaps best be judged from a typical mass spectrometer analysis given in Table 1.

Unfortunately, where there is spectral overlap, analyses are not as simple as the oxygen and nitrogen determinations considered previously. However, as the component spectra of mixtures are additive linearly, equations of the form

> mixture peak height = (concentration of component *A*) × (Intensity at chosen peak of unit quantity of component *A*)
> + Similar terms for components *B, C, D* ...

can be written down so that the quantitative analysis of an "*n*" component mixture then involves, in general, the solution of "*n*" linear simultaneous equations. Furthermore, from these equations a reciprocal or inverse matrix can be formed which gives component concentrations directly in terms of mixture peak heights and numerical factors. These "inverted" equations, of the type

> concentration of component $A = 18.2\ h_1 + 12.5\ h_2 + 9.0\ h_3 + \ldots$ where $h_1, h_2, h_3 \ldots$ are mixture peak heights,

may then be solved readily and quickly with the aid of an electrically- or manually-operated desk calculating machine.

As minor instrumental imperfections cause mass spectra to change slowly with time, maximum analytical accuracy cannot be achieved without periodic recalibration of the instrument in use. However, the spectral changes are small and the spectra obtained on different instruments are sufficiently similar to allow semi-quantitative analysis to be made at all times, provided a suitable library of reference spectra is available. With such a library, qualitative analyses can be made, even though no spectrum of the compound run is available, as the breakdown of molecules under electron impact follows certain arbitrary "rules".

Quantitative Analysis of Organic Materials

Gases

Before the advent of the mass spectrometer, most gas analyses were made by low-temperature distillation, alone or with combustion, absorption, infra-red and ultra-violet techniques.[2] Unfortunately, low-temperature distillation runs, whether made for analytical or fractionating purposes, are time consuming, often taking from eight to twelve hours a sample. It is not surprising, therefore, that mass spectrometers became the basic analytical tool in many gas analysis laboratories, once it was established that they could analyse gases in a fraction of the time taken by the older techniques and with comparable or better accuracies.[2 to 5]

Mass spectrometers, however, whilst basically simple, involve a considerable number of complex electrical circuits, and the cost of a commercial instrument is high compared with other gas analysis equipment. Furthermore, certain laboratories which are already fully equipped with the older apparatus have a relatively low throughput of samples. Consequently, not all hydrocarbon gas analysis laboratories are equipped with mass spectrometers, and the advent of the vapour phase chromatograph[6] has now changed the overall picture. It is worth while, therefore, considering the capabilities of the various gas-analysis tools in more detail. This is done in Table 2.

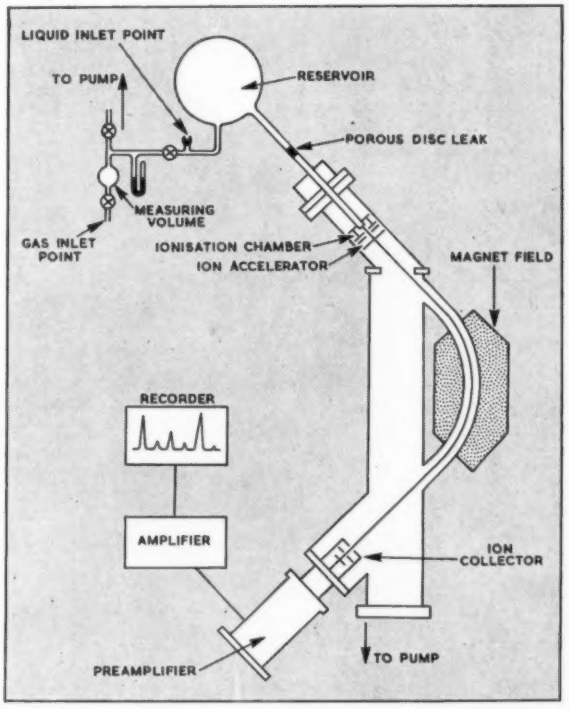

Fig. 1. Diagram of a simple form of mass spectrometer including amplifier and recorder.

From this table one can infer that, before long, vapour phase chromatography will in many instances supplant all other techniques of gas analysis. Even where several runs have to be made on different columns to complete an analysis, the skill required from an operator is so low comparatively that this may well be true. Still, where a varied and heavy analytical load has to be carried out, there is no evidence as yet to indicate that the chromatographic technique is better suited fundamentally to this task than the mass spectrometer. It seems likely, therefore, that this latter instrument will continue to find uses in heavily loaded analytical laboratories, particularly as most of these laboratories will be equipped with digital computers which make the times of mass spectrometer estimations negligible. In laboratories with small to medium throughputs, however, opinions on the most satisfactory techniques are likely to differ. Much will depend on accuracy demands, and on future development work on specific problems for which, at present, there are no satisfactory solutions.

TABLE 2—GAS ANALYSIS EQUIPMENT: RANGE C_1 TO C_5 PARAFFINS AND OLEFINS, N_2, H_2, O_2, CO_2, CO AND 1 TO 3 BUTADIENE WITH TRACES OF C_6

Apparatus	*Range*	*Limitations*	*Time sample run (min.)*	*Man-hours per sample*	*Accuracy*	*Analyses possible per eight-hour day*	*Sample size (mls.)*	*Remarks*
Mass spectrometer	Full range unaided	1. CO and N_2 not determined independently. (CO + N_2 contents accurate.) 2. Individual butenes not determined independently. (Total butene content accurate.) 3. Individual pentenes not determined independently. (Total pentenes accurate.) 4. Analytical accuracy poor if C_6 content>2 mol. %. (Total C_6 only determined.)	10 to 15	1 to 5*	0.3 to 1.0 mol. % per component	30 to 40	1	More accurate and quicker than V.P.C. or I.R. for heavy loads of simple samples. Best machine usually for detection of traces, i.e., <0.1 mol.%
Vapour† phase chromatograph	Full range unaided	1. Five or six different runs necessary for complete analysis of most complex sample. 2. Poor for impurity detection in routine samples. 3. Operator manipulation time high compared with M.S. Greater chances of human errors.	‡ 3 to 20	Approximately two-thirds of requirements of M.S. for analogous information	Approximately two-thirds of that of M.S.	30 to 40 on multicolumn instruments	2 to 5	Accuracy can be improved at expense of running time. Techniques not yet sufficiently standardised.
Infra-red spectrometer	Selected fractions only	1. H_2, O_2 and N_2 cannot be estimated. 2. Four or five fractions necessary for full analysis of most complex sample—using I.R. and fractionation technique.	10 to 20	Approximately same as M.S. where analyses feasible	Approximately same as V.P.C. where analyses feasible	Entirely dependent on sample complexities. (Usual to run in conjunction with distillation equipment.)	20 to 200	Possible to combine with V.P.C. if sample requirements are reduced and/or V.P.C. fractionating gear is developed, with large reductions in fractionating time.
Ultra-violet spectrometer	One to three butadiene estimates only		20		As I.R. in general			Excellent for estimating traces of dienes.
Rodbielniak low-temperature distillation equipment	Full range	1. Without auxiliary equipment information given very limited, e.g. total (H_2+N_2+Co_2+Methane), total C_2, total C_3. 2. Very slow. 3. Poor results on traces of high boiling materials unless "chaser" techniques are employed as a routine.	240 to 720	Approximately three times M.S. requirements	Approximately half that of M.S.	1 to 2	1000 to 5000	Normally used in combination with adsorption, combustion and I.R. techniques. Accuracy can be improved at expense of time taken.

* Dependent on sample complexity, sample throughout, accuracies demanded and calculation aids available. † Information quoted obtained in these laboratories on own equipment. ‡ Figures apply to a single run on a single column.

Liquids and Solids

Sample Handling

The handling of liquids and solids presents problems somewhat different from those encountered in gas analysis. Before a sample can be introduced successfully into the mass spectrometer, it must be established that at the temperature of the inlet system the material will have a vapour pressure of approximately 50 microns and, further, that at this temperature a representative sample can be obtained. Although this requirement can be met at room temperatures by many mixtures that boil well beyond 100°C, a heated inlet system is necessary for the study of most organic liquids and solids. Suitable systems involve minor and major engineering and chemical problems in that the chance of reaction between sample and equipment increases at higher temperatures and high-temperature vacuum joints and taps are not easily made.

O'Neal and Wier[6] have, however, successfully overcome all these problems for hydrocarbons and have succeeded in running materials of molecular weights around 800 in a plant heated to a temperature of approximately 350°C. Molten gallium is used for sealing taps and joints. Under these conditions, O'Neal[7] reports that all materials that can be taken as the "overhead" from a molecular distillation can be run without decomposition in the inlet system and spectrometer. Additional difficulties are experienced when handling polar materials, as such compounds are readily absorbed on glass and metal surfaces and may be "lost" on the walls of the inlet system. Fortunately, by heating this system and by flushing it with a quantity of the sample to be studied prior to the analytical run, errors due to this cause may be reduced.

Component Analyses

Unfortunately, the complexity of organic mixtures increases rapidly with boiling range. Furthermore, the mass spectra of isomers show more similarities than the spectra of materials of differing molecular weight. Consequently, the information that can be given from mass spectral analyses of samples in boiling ranges above 50°C is somewhat restricted. In general, it is not practicable to analyse completely samples which contain more than ten or twelve components, even in the C_6 and C_7 region. Full analyses in higher ranges are impossible unless samples are first prefractionated. For these reasons, the reported applications[9 to 17] of mass spectrometry in this field, as can be seen from Table 3, are somewhat restricted.

Other physical methods of analyses, e.g., infra-red spectroscopy, suffer somewhat similar drawbacks with regard to sample complexity, and the majority of the analytical work in this field is done by somewhat laborious techniques involving fractionation of the sample followed by analysis of the fractions. It should be noted that infra-red spectroscopy has achieved many successes because of the dissimilarities between the spectra of isomers.

TABLE 3—MASS SPECTROMETER ANALYTICAL APPLICATIONS: ORGANIC LIQUIDS AND SOLIDS

	Analytical Accuracy
C_1 to C_4 alcohols ...	0.5 mol. % per component
Chlorinated C_1 and C_2 compounds	0.2 mol. % per component
C_1 to C_6 organic acids ...	0.6 mol. % per component
C_5 to C_8 aliphatic hydrocarbons	0.1 to 2.0 mol. % per component
C_6 to C_9 aromatics ...	1.0 mol. % per component
Miscellaneous aldehydes, ketones and esters ...	0.1 to 1.0 mol. % per component
Thiophenes	Not established with certainty, but not worse than 4 mol. % per component or group, and often better than 0.4 mol. % per group
Phenols	
Amines	
C_5 to C_{10} hydrocarbons (type analyses) ...	

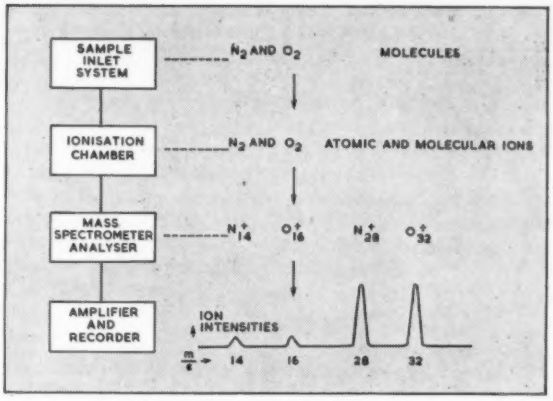

Fig. 2. Diagram showing solution to a simple analytical problem. The sample for analysis was a nitrogen hydrogen mixture.

Most physical methods laboratories, however, are concerned with pressing day-to-day analytical problems which demand a rapid, if imperfect, solution. A combination of the somewhat dubious results given by several methods is then often necessary, and in this connection the mass spectrometer is at least the equal of all other tools. However imperfect the information given may be (e.g., concentration of aldehydes + ketones + paraffins = 50%), the quantitative figures are normally good because all materials have approximately equal sensitivity coefficients. Furthermore, because the mass spectrum can be correlated with an atomic or molecular property (e.g., mass) that has a readily appreciated physical significance, qualitative data are sound even when ambiguous. Unfortunately, this aspect of mass spectrometry is not a fruitful subject for discussion. In addition, the development of vapour-phase chromatographic analytical and fractionating techniques will ultimately revolutionise this field.

Type Analyses

The spectral similarities between isomers and compounds of the same type have been turned to advantage in hydrocarbon-type analyses, where those compounds with similar spectra are determined as a group, no attempt being made to estimate individual group members. Instruments have been used not only to give "routine"-type analyses (similar to the examples quoted in Table 4) that are competitive in accuracy and man-hour requirements with analyses made by alternative procedures, but also for assays impossible by other methods. In this latter connection O'Neal has developed many mass spectrometer techniques for the type analysis of hydrocarbon samples in the molecular weight range 200 to 800, and applied these to make the first successful studies of the constitution of such petroleum products as gas oils, lubricating oils and waxes. While assessments of the accuracy of these techniques are very difficult to make, particularly as very few pure materials are available for instrument calibration, he has succeeded in showing that the methods are sound. For example, it was indicated by mass spectrometer analyses that the urea adduction process for the estimation of *n* paraffins was inapplicable to waxes. This was confirmed by later studies on purified waxes.

For successful type analyses it is essential that all the materials classified in one category are similar, and yet that all are dissimilar from those in other categories. It is not always clear, however, even on chemical grounds, into which type a compound falls. For example, a C_{40}

TABLE 4—TYPE ANALYSES OF HYDROCARBON MIXTURES: TYPICAL RESULTS

SAMPLE 1: *Cracked Gasolines*					
Paraffins	45	mol. %	± 2	mol.	%
Naphthenes and straight chain mono-olefins	35	„ „	± 3	„	„
Cyclic olefins + diolefins ...	5	„ „	± 2	„	„
Aromatics	15	„ „	± 1	„	„
SAMPLE 2: *Straight-run Gasolines*					
C_5 paraffins	1.0	„ „	± 0.3	„	„
C_6 paraffins	10.0	„ „	± 1.0	„	„
C_7 paraffins	15.0	„ „	± 1.0	„	„
C_8 paraffins	7.0	„ „	± 1.0	„	„
C_9 paraffins*	8.0	„ „	± 3.0	„	„
C_{10} paraffins	<1.0	„ „	± 0.3	„	„
Total naphthenes	8.0	„ „	± 1.0	„	„
C_6 Benzene	5.0	„ „	± 0.5	„	„
Toluene	15.0	„ „	± 1.0	„	„
C_8 aromatics	15.0	„ „	± 1.0	„	„
C_9 aromatics	10.0	„ „	± 1.0	„	„
Higher aromatics	6.0	„ „	± 0.5	„	„

* Figure possibly high due to presence of naphthalene. Confirmed by ultra-violet.

mono-olefin might be characterised best as a paraffin, particularly where the double bond appears near the end of the chain. In fact, most methods of type analysis would tend to classify the material in this way. There are often important differences, however, in the classifications made by the various techniques (e.g., chromatography, refractive index measurements, bromine numbers) and for this reason all methods are valuable. Despite the fact, therefore, that mass spectrometry[18, 19, 7] has had some of its more striking successes in this field, it is unlikely to replace other methods. The development of more refined techniques combining several methods is more feasible.

Qualitative Analyses of Organic Materials

So much effort has been devoted to quantitative analyses of extremely complex mixtures where great instrumental stability is required to ensure that the relative intensities of the various ion species formed from any particular compound remain constant for the maximum possible time, that the use of the instrument for the qualitative analyses of compounds that might disturb the instrument's performance has been neglected. Early papers by Rock and Zemany pointed out the possible uses of the instrument in this field, tabulating in a systematic manner all the then established facts, but the power of the instrument was not demonstrated until Beynon[20] published information on a technique that he has been long using with considerable success.

The approach follows classical lines in that measurements of the masses of the most important ions produced are determined with the greatest precision the instrument in use will allow. The small differences from whole numbers in the masses of the various atoms taken in conjunction with these measurements then enables deductions of the empirical formulæ of ions to be made. This is best understood by reference to a simple compound such as nitrogen, which has a molecular weight of 28.01508. Clearly, the presence of an ion beam at mass : charge ratio $\simeq 28$ would not, in itself, indicate that nitrogen were present in a sample, as the mixture might contain carbon monoxide or any of several organic materials. However, the mass of the CO^+ ion is 28.00386 and the mass of the $C_2H_4^+$ ion is 28.04024. Consequently, if the mass of the ion at $\frac{n}{e} \simeq 28$ can be determined with an accuracy of $\simeq \frac{1}{2000}$, the presence or absence of nitrogen can be confirmed conclusively. As a confirmation that empirical formulæ are assigned correctly, use can be made of the known isotopic ratios of the elements.

For the example quoted, the ratio of the ion beams at m/e values 29 and 28 would be measured and the known N_{15}/N_{14} ratio used to calculate the expected $[N_{15}.N_{14}]^+ / [N_{14}.N_{14}]$ ratio.

After establishing the molecular formulæ of various ions, further information on molecular structural groups may be deduced from the empirically established "laws" governing the break-down of molecules under electron impact. An extremely comprehensive series of spectra from which such "laws" may be deduced is published by the American Petroleum Institute.

By these various procedures it is often possible to determine the formula and structure of materials uniquely, the chief limitation being the accuracy with which ionic mass can be determined and the ease with which ions of very similar mass can be segregated and identified. Here it is worth recording that, while the majority of the work to date has been done on single-focusing instruments, the materials examined rarely exceeded a molecular weight of 200. For the higher boiling compounds, double-focusing instruments of the highest possible resolution will be required.

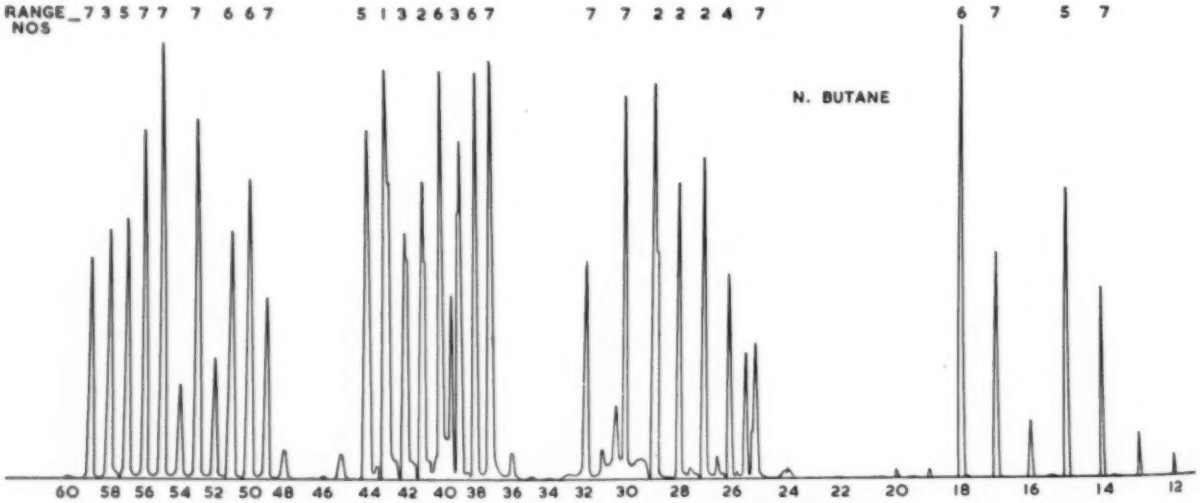

Fig. 3. A typical spectrum obtained from a substance containing a large number of atoms (n-*butane*).

Analysis of Inorganic Solids

Although the main problems of interest in the chemical industry concern organic materials, there is an increasing consciousness of the importance of minor inorganic elements, both in catalysis and the physical properties of materials used for fabricating plant and instruments.

The chief difficulty experienced with mass spectrometers for the quantitative and qualitative analysis of solids is the production of ions representative of the sample under study in a manner that enables the ions to be sorted readily. Using comparatively simple instruments and a somewhat specialised technique, a certain amount of work has been done on elements that are ionised easily, e.g., K, Na, Ur, Th.[21, 22] Usually chemically pure elements in which the isotopic distributions are different from normal are added in known amounts to the mixture to be analysed. Measurements of the isotope distributions on the original sample, the chemically pure elements and the "diluted" sample will then allow minor element concentrations in the original sample to be determined very accurately (1 part per million). However, not all elements can be ionised easily and ion sources suitable for use with the less readily ionised materials, e.g., spark and arc discharges, produce ions with such a large spread of energies that single-focusing intruments of the type discussed previously are unsuitable. Double-focusing, in which ions of the same mass may be focused at the same point irrespective of their initial energies, must be employed.

Such instruments are now available commercially and recent developments have shown that the mass spectrometer may play an important part in inorganic analyses.[24] It would appear that it can analyse satisfactorily for element concentrations in the range 0.1 to 10 parts per million.[23, 24] It is likely, therefore, to fill a gap between the spectrochemical techniques, which in general are satisfactory down to about 10 parts per million, and radioactivation techniques, which are satisfactory at considerably lower levels, i.e., well below 0.1 part per million. Naturally, as all three techniques have weak points within their broad working ranges, there will be a certain amount of overlap and further development work may well change the limits quoted.

Plant Control

Although there are a considerable number of mass spectrometers devoted to routine sample analyses, very few attempts have been made as yet to install automatically-operated instruments on plants. The integration of such equipment into overall control schemes and provision for instrument maintenance present problems equally as difficult as "robotisation" of the spectrometers. However, there are a few such instruments in use[25, 26] similar to the one illustrated, and their numbers will undoubtedly increase in the future. Moreover, there will be considerable competition from the simpler infra-red and vapour-phase chromatographic analysers, and the position with regard to plant instruments is somewhat obscure. The situation is further complicated by the rapid development of digital computers, which seem certain to find many uses in the control of chemical plants. In this event, a single complex instrument like the mass spectrometer, handling several problems simultaneously, might be better than a battery of simpler instruments.

Conclusions

An attempt has been made to survey broadly the analytical applications of mass spectrometry within the chemical industry. No attempt has been made, however, to cover all the applications in detail and, in particular, several important allied uses of the instrument (e.g., leak detection on large plant) have been omitted entirely. Furthermore, no references have been made to the more fundamental studies, e.g., reaction kinetics, in which the mass spectrometer is being employed, and from which newer mass spectrometric techniques will undoubtedly develop (e.g., the use of ion sources in which close control of the fragmentation of the molecules may be exercised).

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Catalyst Manufacture at Clitheroe

THE I.C.I. CATALYST FACTORY at Clitheroe, a branch of the Billingham Division, and probably the only factory in the world concerned exclusively with the manufacture of catalysts, has in recent years been considerably extended and modernised, and, as a result, ranks as an outstanding example of efficient small-scale manufacture. The catalysts are made mainly in the form of near-spherical granules and small cylindrical pellets and are used for fixed-bed processes. Some catalysts are also manufactured in powder form and presumably can be used as a fluidised catalyst. While the 2500 tons annual output may seem very small, it is sufficient to meet the needs of I.C.I., both internally and for outside sales.

Catalysts obtainable in cylindrical form contain such active ingredients as chromia, promoted iron oxide, copper and zinc oxides, copper oxide-chromia, nickel oxide-chromia and nickel supported on kieselguhr. The copper oxide-chromia and nickel kieselguhr catalysts are available in powder form also. Other catalysts include nickel oxide, which is produced in hollow cylindrical rings, zinc oxide in pill form and promoted iron oxide as fused granules.

The plant, distributed over three separate buildings, is a general-purpose one, and is designed to convert a number of solid raw materials into several different products at any one time. The first stage of the manufacture is the preparation of oxides from solutions of the various metals. After washing, the precipitates are transferred to Sweetland filters and the wet cake is passed to drying ovens. Several types are available for this operation, including continuous band, continuous calcining or tray types. Most of these ovens are gas-fired, but steam and electric drying ovens are also available. The dried and decomposed materials are subsequently crushed, blended and formed finally into the shapes in which they are to be used. For pelleting, high-speed rotary machines are used which are capable of outputs as high as ½ million an hour.

AMERICAN LETTER

Pulp and Paper Progress in America

CONSIDERABLE progress in the pulp and paper industry in the United States is reflected by the recent expansion of Bowaters Southern by the development of a continuous pulping process and by numerous research projects now being undertaken at the University of Maine.

The Bowaters Southern Paper Corporation, a division of the British Bowaters paper empire, increased the capacity of its news mill at Calhoun, Tennessee, during 1957, by at least 50% when it put its third machine in operation. Capable of running at 2500 feet a minute, the new unit turns out more than 300 tons of newsprint a day. The new machine, of course, has necessitated enlarged facilities for handling wood, preparing groundwood, metering pulp, finishing, shipping and developing power. In all, the expansion has meant an outlay of some £11 million.

New equipment includes a three-section Canadian Ingersoll barking drum, 68 ft long and 12 ft in diameter, additional conveyors and a 21in. Cambio debarker. Four hundred tons of groundwood a day are supplied from six Great Northern Waterous grinders, each of which is driven by a 6000-hp synchronous motor. Pulp is refined by means of two 36-in. Sprout-Waldron units and screened through four Cowan screens and three 5 × 14-ft Allis-Chalmers vibrating coarse screens. Additional equipment includes six new Impco deckers 8 ft in diameter and 16 ft long; two tile chests provided with Shartle agitators for decker stock and blending; a Cowan proportioning system for groundwood, bleached kraft, hardwood pulp and broke; two Jones jordans; and a 20-ft Impco save-all 12 ft in diameter.

A new Babcock & Wilcox boiler, which can be oil- or gas-fired, supplying 6000 lb. of steam a minute at 900°F and 850 psig, has also been installed.

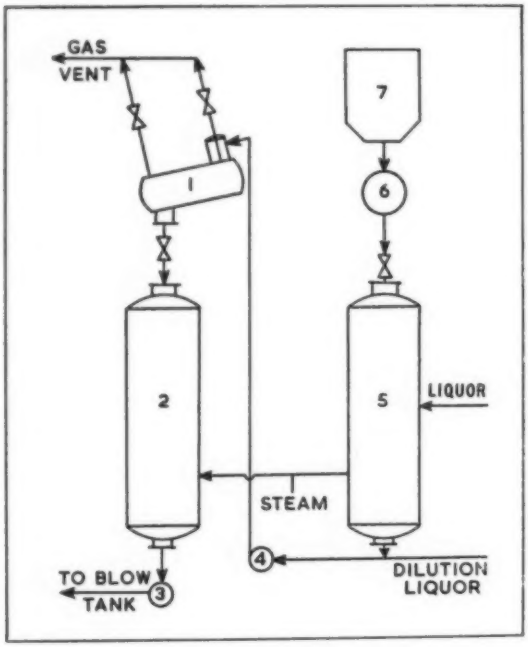

Fig. 1. Diagram of the Condi pulp treatment plant showing: (1) drainer; (2) digester; (3) ejector; (4) pump; (5) impregnator; (6) chip feeder; and (7) chip bin.

Continuous Pulping

Batch processes have always characterised cooking systems for chemical and semi-chemical pulps. However, a new process, the Condi, now undergoing active development in America, affords continuous operation. It consists of three stages:

(1) Preparation of chips so that they will absorb cooking liquor readily; (2) impregnation of chips so that cooking liquor of low but uniform concentration can be employed; and (3) cooking with a predetermined amount of chemicals.

In the Condi process chips are fed to a small bin (see Fig. 1) and are then fed continuously by means of a rotary bin discharger into the steaming zone of an impregnator through a multi-vane feeder which is provided with equalising pipes that decrease the steam pressure and minimise the amount of steam lost from the impregnator. The chips are presteamed in the upper portion of the impregnator at a pressure above atmospheric for about five minutes to drive off air that surrounds the chips, to compress the air within the chips, to mix it with steam and to increase the rate of penetration of liquor. The chips enter a bath of cooking liquor, the temperature and concentration being controlled automatically.

A scraper at the bottom of the impregnator delivers the chips and liquor to a pump which carries them to a drainer and from here they go to the digester to be cooked at a definite temperature for a definite time. In this stage, lower ratios of liquor to wood are possible than in other processes because of the earlier presence of chemicals in the chips. Another scraper at the bottom of the digester delivers the cooked chips to an axial-flow ejector from which they pass through adjustable orifices to the blow tank.

In the process, liquor always moves through a column of chips. Other advantages are: controlled flow of liquor, chips and steam; no thermal cycles; continuous removal of non-condensible gases; constant temperature and liquor concentration at any given point; and minimisation of the human factor.

Research at Maine University

Of seventeen excellent research projects in pulp and paper technology at the University of Maine, three deserve particular mention. The first of these shows that an evaluation of the pulping qualities of red pine, through the use of ammonia-base cooking liquor, will determine the effects of the composition of the liquor, maximum cooking temperature and pressure, penetration time to 100°C and total cooking time.

Since the presence of sodium silicate in some pulps is detrimental, an effort is being made to develop some other stabiliser for use in the peroxide bleaching of groundwood. At the University, trials will be made at 10% consistency, and at a bleaching time of two hours at 120°F with a peroxide equivalent of 2% sodium peroxide based on oven-dry pulp.

Finally, an attempt has been made to correlate flow data for synthetic fibre stocks with those for long-fibre bleached sulphite stock at various consistencies. The effect of fibre length on shear resistance and suspension number, which is analogous to the Reynolds number for Newtonian fluids, was determined. Correlation with friction factors for pipes of various materials should result.

Doctor Joseph Priestley

's luck was rather biestley;
with mistaken care
he labelled oxygen

'dephlogisticated air'!

Very hard luck to discover an element which could make you famous—and then mistake it for something else; but many a scientific discovery has been made while the researcher was working on an entirely different tack! At least in these days, the scientist has the help of well-made reliable instruments—often from W. G. Pye Ltd. Pye Scientific Instruments are well-known in industry and in research, where the craftsmanship and thought that go into their manufacture and design are much appreciated by the Priestleys of today.

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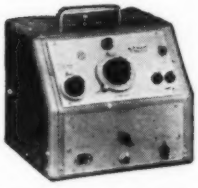

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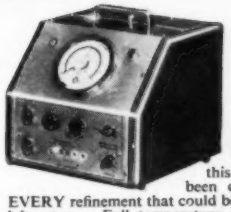

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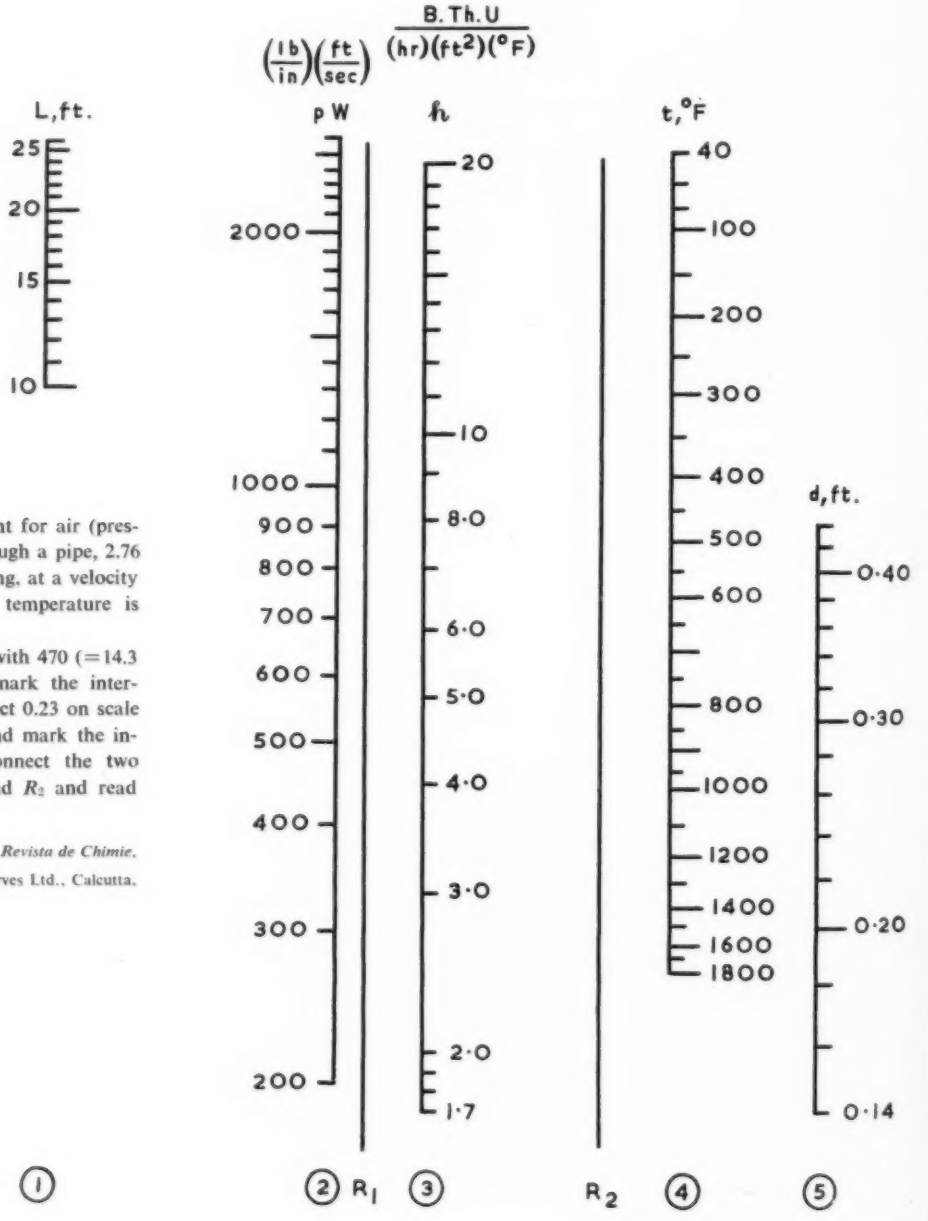
HEAT-TRANSFER COEFFICIENT FOR NATURAL CONVECTION

A recent nomogram[1] solves the Nusselt-Gröber equation for the estimation of film coefficient in heat transfer to air through natural convection. The equation is:

$$h = 23.7\ L^{-0.05}\ d^{-0.16}\ (pw)^{0.79}\ b$$

where h = film coefficient, kcal/(m²)(hr)(°C);
L = length of the pipe, m;
d = diameter of the pipe, m;
p = gas pressure, kg/cm²;
W = linear velocity of gas, m/sec.; and
b = function of gas temperature.

For the convenience of our readers, we present here a nomogram, prepared for us by O. P. Kharbanda,* with the commonly used engineering units instead of the metric units. Also, for greater utility, the b scale has been calibrated directly in terms of temperature in °F.



EXAMPLE:

Estimate the film coefficient for air (pressure = 14.3 psi) flowing through a pipe, 2.76 in. in diameter and 16.4 ft long, at a velocity of 32.8ft/sec. The average temperature is 1472°F.

Connect 16.4 on scale (1) with 470 (=14.3 × 32.8) on scale (2) and mark the intersection point with R_1. Connect 0.23 on scale (5) with 1472 on scale (4) and mark the intersection point on R_2. Connect the two intersection points on R_1 and R_2 and read $h = 3.4$ on scale (3).

[1] Grinstain, T., and Slacman, M. *Revista de Chimie*, 1957, **8**, cover IV.
* Present address: c/o Simon-Carves Ltd., Calcutta, India.

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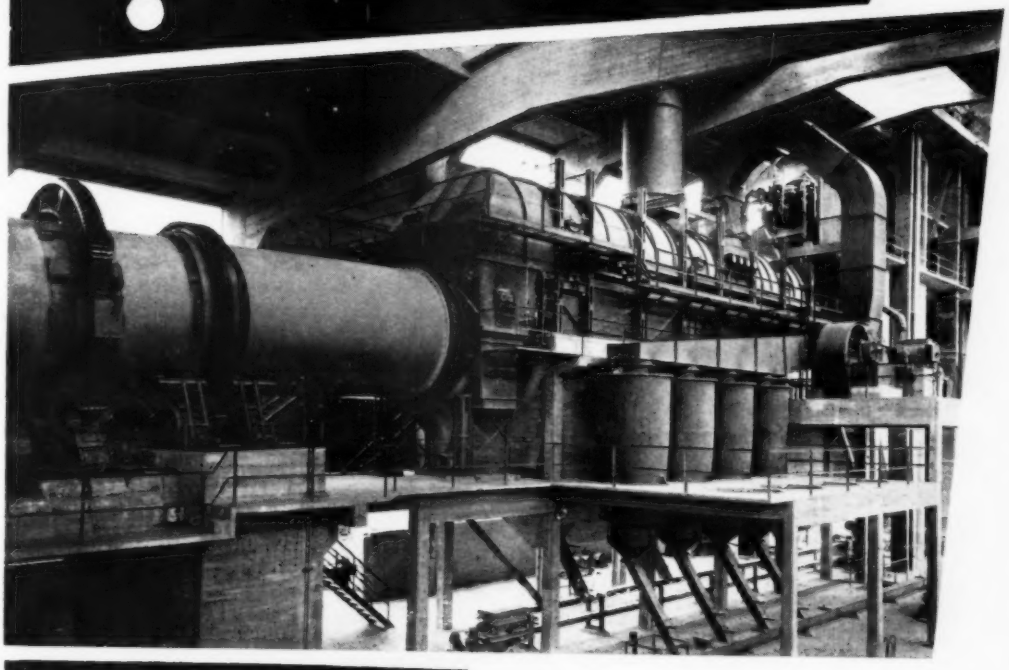

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PROCESS ENGINEER'S NOTEBOOK

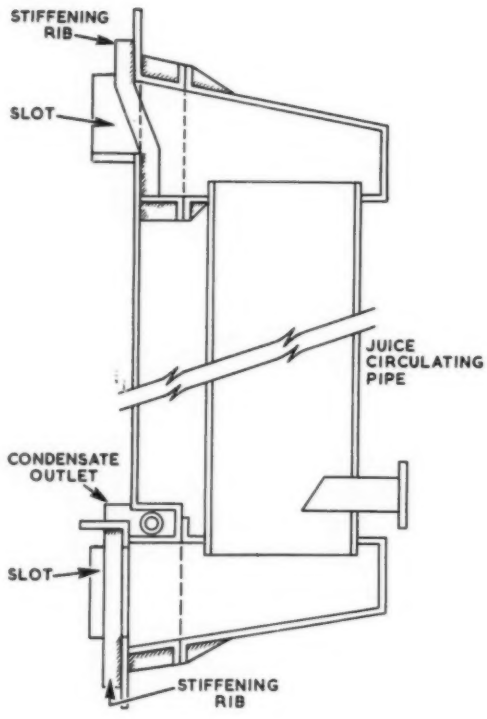
Increased Capacity from Modified Evaporators

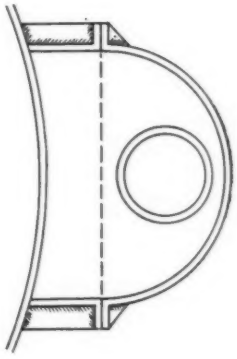
ONE METHOD of increasing the capacity of existing evaporators of the Robert type is to increase the length of tube in the calandria. A better method is to redesign the calandria without increasing the tube length. In one procedure the internal juice-circulation pipes in the calandria are removed and replaced by external circulation connections, as shown in the accompanying diagrams. The bottom tube-plate is replaced by one having a very slight slope (see diagram). The tube-plate is, in fact, made up of two halves and welded together to give the necessary slope.

This alteration has the advantage of reducing corrosion of the tubes near the bottom of the calandria by preventing the accumulation of concentrate at the tube-plate. The normal tubular condensate outlet at the calandria is replaced by a slot of approximately $\frac{5}{8}$ to $\frac{3}{4}$ in. in width by 8 to 12 in. in length. This arrangement, which is also shown in the diagram, has the advantage of a much quicker condensate removal, as the normal depth of condensate obtained with this arrangement is not more than $\frac{3}{8}$ in.

There are no tubes in the calandria centre, and the space thus left is used to enable the fitting of a steam pipe. This allows the steam to be fed to the centre of the tube nest and, therefore, gives improved steam distribution. It is possible to arrange a number of inlet pipes introducing steam at different heights up the calandria. The dimensions of the external circulation tubes are given in the following table:

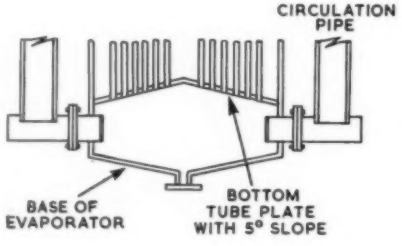
In order to prevent excessive level of juice, the circulating pipes are installed as low as possible at the bottom of the evaporator body, and as far below the lower tube-plate of the calandria as possible. The cutting of slots in the walls of the evaporator reduces its mechanical strength and, for this reason, it is necessary to add reinforcement near the slots including pads and strips, as shown in the diagram. It is possible to increase the capacity of evaporators by as much as 50% of their original capacity by this kind of modification, especially if a tube pitch closer than the original is used. *W.G.C.*

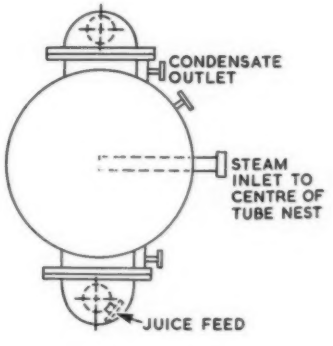




PLAN OF CIRCULATION CONNECTION

Heating surface (sq. ft)	Diameter of new circulation pipes (in.)	Length of slot for juice outlet (in.)	Height of outlet above upper tube-plate (in.)	Inlet connection (in.)	Outlet connection (in.)
2150-3230	12	$27\frac{1}{2}$	5	$9\frac{3}{4}$	5
4300	12	$31\frac{1}{2}$	5	$9\frac{3}{4}$	5
6550	$15\frac{1}{4}$	$31\frac{1}{2}$	5	$9\frac{3}{4}$	5
8600-10,800	$15\frac{1}{4}$	47	6	$13\frac{1}{4}$	6
13,000-16,000	20	53	7	$13\frac{1}{4}$	8

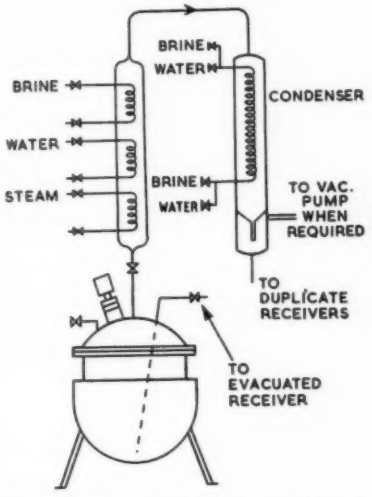




Small-scale Plant for Organic Preparations

IN MANY ORGANIC preparations carried out at the pilot-plant scale, it is often necessary to conduct a reaction in a solvent medium and to finish up with a product which is free from solvent. The usual method is to make use of a jacketed or electrically heated vessel provided with a reflux condenser. When the reaction is completed the practice is to evaporate the solvent and divert it to the receiver in order to obtain a product as free as possible from solvent. This method is not always successful, because some solvent will condense in the vapour pipe leading to the condenser and return to the vessel.

One method of avoiding this difficulty is to use a system similar to that illustrated. This uses a glass condenser with three separate coils. The lower-most coil is connected to a supply of low-pressure steam, whereas the two upper coils are connected to brine or cooling-water supplies. During the reaction, reflux is carried out by means of one or other of these two coils, but when evaporation is required steam is applied to the lower-most coil. This ensures that the vapours are superheated sufficiently to avoid condensation in the pipe-line leading to the main condenser, so that return of condensed solvent to the

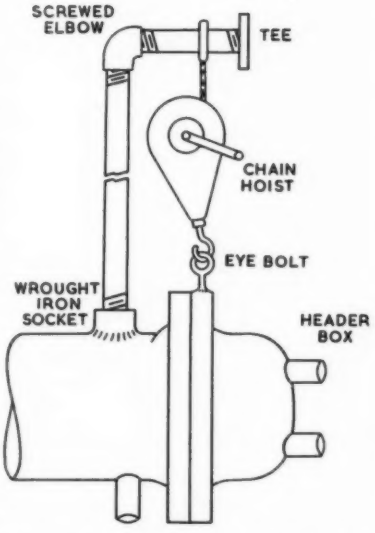


vessel is prevented. Brine cooling is provided if the boiling point of the solvent is sufficiently low to make water cooling ineffective, which may be the case when the evaporation has to be performed under vacuum. As mentioned in an earlier issue of *British Chemical Engineering* (October, 1957, page 567), it is useful to colour the brine with a dye so that it can be readily seen that the correct cooling medium is circulating in the primary condenser.

Inspection of Heat Exchangers Made Easy

INSPECTION, and therefore maintenance of heat-exchanger tube-plates and tube-nests, can be greatly assisted if the heat exchanger header-box can be removed without manhandling. A simple and inexpensive way of doing this is shown in the accompanying diagram. A wrought-iron screwed socket—generally 2-in. B.S.P. is big enough—is welded to the top of the shell near the tube-plate, a short length of tubing being threaded into the socket at one end and into a screwed elbow at the other. This fitting is not tightened up on the vertical tube, but is left free to move.

Another short piece of tubing, again threaded at each end, is screwed into the elbow with its other end terminated by a screwed flange. The horizontal arm formed by this piece of tubing carries the ring of a chain hoist, the purpose of the flange being to prevent the ring from leaving the arm. The hook of the hoist is threaded through an eyebolt fitted to the header-box and once the header-box bolts have been loosened, the load



is taken by the hoist. After removing the bolts, the header-box can be withdrawn and pushed to one side. Inspection of the tube-plate and the tubes can then proceed.

Sealing Leaks on Fractionating Columns

AN UNUSUAL REPAIR was carried out on a leaking flanged joint of a coking plant's fractionating column. The leaking fluid was a light aromatic oil, with a high concentration of naphthalene, at 100°C. The usual repair methods would have meant interrupting production, the rigging of hoists and the partial dismantling and lifting of the column above the point of leakage in order to fit a new joint ring.

The principle of the method adopted consists of applying a thermosetting material while still in the semi-plastic state to the leak. The result is that heat causes the sealing material to melt, when it is then in a fit state to be forced under pressure into the leak. Further action of heat causes the compound to solidify and, therefore, to form a permanent seal. In practice, an adaptor is fitted at the flange to isolate the zone of leakage from the remainder of the circumferential joint and this allows the sealing mixture to be directed solely to the leak. For this purpose, the adaptor is fitted with a connection for the injector gun which is charged with the sealing compound in the first place. This procedure may necessitate the removal of a bolt from the flange, in which case a boiler clamp must first be fitted across the flanges before removing the bolt.

In this particular case it was not necessary to take the column out of production while the sealing operation was being performed.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Spanish Iron Works

Head Wrightson were responsible for a major part of a new iron and steel works recently commissioned at Avilés, including ore handling, sintering, blast furnace and gas cleaning plant. The Head Wrightson continuous sinter machine measures 120 ft long by 6 ft wide with 720 sq. ft of pallets capable of producing 45 to 75 tons per hour according to the permeability of the material loaded. The No. 1 blast furnace constructed by the company has a production capacity of 1200 tons per day. The No. 2 furnace is of American manufacture and produces 1300 tons per day. Furnace gases pass through a collector chamber where the coarsest dust is deposited by expansion and change of direction of fluid. The gas then passes through a centrifugal collector, where the gas enters tangentially and peripherically, leaving vertically through the centre of the top. The gas is led to a washer entering through the lower part, and rising in counter-current with the falling water, which is injected by two levels of sprays, enabling the water to collect the medium-sized dust. Finally, it is treated in electrostatic precipitators where the fine dust is separated.

Pakistan Fertiliser Production Plans

The I.C.A. have agreed to extend to Pakistan $10 million towards the foreign exchange costs of a fertiliser plant or plants to utilise natural gas, each having an annual capacity of about 117,000 tons of urea or its equivalent. Pakistan is not compelled under the terms of the agreement to accept the bid of any American company to erect or operate the plants. The Government of the country is also considering the establishment of two fertiliser factories financed by private American and Pakistan capital; and the supply on long-term credit by "an American party" of machinery for a fertiliser factory. The Pakistan Finance Minister is reported to have said that if private capital could be attracted to finance the project on reasonable terms there would be no need for the Government to handle it.

German Petrochemical Company

Farbenfabriken Bayer Leverkusen and B.P.'s German associate, B.P. Benzin und Petroleum A.G., Hamburg, have established a joint company named Erdoelchemie G.m.b.H. The company will have its office at Leverkusen. The initial capital is DM 50,000 in which Bayer and B.P. each have a 50% share. The company will increase its capital in due course; present plans provide for a total expenditure, as already published, of about DM 240 million (£20 million). Erdoelchemie G.m.b.H. will operate a factory at Dormagen, now being built for petrochemical production. The plant is expected to have reached the first stage of completion by the end of 1958.

New Indian Plant

A new plant for the manufacture of superphosphate and sulphuric acid has been opened in Madras. It has a capacity of 33,000 tons of superphosphate a year, which represents over half the target set by the Planning Commission for the current year. The Caltex oil refinery at Vishakhapatnam, having a capacity of 700,000 tons annually, went on stream recently. It is smaller than the Burmah Shell and Standard Vacuum refineries, which process respectively about 2 million and 1.2 million tons of crude oil annually. The total production of all refineries in India more than meets the country's present needs of fuel, oil and motor spirit, but kerosene, aviation spirit and certain specialised oils will still have to be imported.

Mexican Soda and Petroleum Products

Production of caustic soda in Mexico has risen from 6140 metric tons in 1951 to 25,546 metric tons in 1956, about 80% being produced at present by Sosa Texcoco S.A. The consumption of sodium alkalis last year was equivalent to 156,739 metric tons of sodium carbonate. During 1956 Mexico produced the following petroleum by-products in the quantities indicated (metric tons): creosote, 8200; benzolic products, 3860; tar, 9120; and bitumen, 6000. Ethyl alcohol produced from sugar cane amounted to 39.9 million litres in 1956, a decrease of 3.6% compared with 1955.

French Petroleum Production

During the first five months of 1957 the output of petroleum products in France and French overseas territories amounted to 684,000 tons, as compared with 541,000 tons during the same period in 1956. Of this, 605,000 tons came from metropolitan France, 39,000 tons from North Africa and 40,000 tons from tropical Africa. The production of natural gas in that period amounted to 159,000 million cu. m., as compared with 146,000 million cu. m. during the corresponding period of 1956.

U.S. Record in Cyclic Intermediates

The output of cyclic intermediates in the U.S.A. in 1956 reached the record amount of 6600 million lb., 10% more than the previous record of 6016 million lb. for 1955. About three-fifths of the 1956 output was consumed by the producing concerns in further manufacture and the remainder was sold. The amount sold was 2556 million lb., valued at $444 million, compared with 2285 million lb., valued at $408 million, in 1955.

Titanium Dioxide at Vera Cruz

Industrias Quimicas Basicas de Mexico S.A. is to build a titanium dioxide plant near Vera Cruz, and for the purpose will receive technical assistance from the Glidden Co. of the U.S.A. Investment in the new plant will be 80 million pesos (£2.3 million), of which 55% will come from the Mexican company and Nacional Financiera and 45% from abroad in credits for equipment to be guaranteed by Nacional Financiera.

Australian Acid Development

The first plant in Australia to manufacture sulphuric acid from oil refinery gases is to be built at Geelong, Victoria, for Shell Refining (Australia) Pty. The plant will produce 100 tons of sulphuric acid a day and will make use of hydrogen sulphide, which, at present, is not recovered. The acid will be used in the manufacture of fertilisers and for other industrial purposes in Australia.

Spanish Cement

Cement production in Spain in 1956 amounted to 3,999,757 tons, 7% more than in 1955. At the end of the year the 48 cement factories operating in the country provided a total annual capacity of 4,757,200 tons. New plant with a total capacity of 400,000 tons is planned to be commissioned by the end of 1957. New factories authorised and extensions to existing plant will increase the production in Spain by 1,166,000 tons.

Aluminium from North Australia

The chairman of the Australian Atomic Energy Commission has suggested that an aluminium industry using nuclear power should be established in North Australia to solve the development of that vast sparsely-settled region. The extensive deposits of bauxite which have recently been discovered in North Queensland, he added, would need large supplies of electric power for their exploitation.

Israel Paper Production

In doubling the output of paper at the Hadera mills to 28,000 tons annually, and in the constructing of a mill for pulp mainly from local maize stalks, $10.5 million are to be invested. The corner stone of an extension to the mills as part of this programme was laid recently.

Burma Acid Plant Commissioned

The first sulphuric acid plant to be erected in Burma was recently put on stream. It is capable of producing 10 tons of standard sulphuric acid a day, an amount which is estimated to be two or three tons in excess of the present needs in the country.

Refinery Extensions at Rotterdam

Caltex Oil have decided to extend their refinery works in Rotterdam considerably in the next few years. The plans provide for, among other extensions, the construction of new platforms for the platinum refining of petrol.

U.S. Polythene Plant

National Petro-Chemicals, a company jointly owned by the National Distillers & Chemicals and the Panhandle Eastern Pipeline, is to build a new polythene plant with a capacity of 75 million lb. a year. The site of the plant has not yet been disclosed, but the plant is expected to be completed by late 1958.

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● *The illustration shows a power driven agitator reactor unit made of stainless steel*

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Book Reviews

Chemical Engineering in the Coal Industry

Edited by Forbes W. Sharpley

Pergamon Press, London, 1957, 142 pp., 50s.

THE nationalised coal industry started from a heritage of science neglected. On a relatively slender base of a few hundred people, the much-maligned Coal Board has built a scientific department of about 3000; research expenditure alone amounts to almost one and a half million pounds a year. This is no mean achievement for an industry that may be thousands of years old and is certainly hundreds. For a D.S.I.R. report last year confirmed—as one might have expected—that long-established industries tend to be conservative. It is the newer ones, aircraft, electrical engineering and chemicals, which have spent heavily on research and reaped the advantage.

Drawing heavily on scientists experienced in other fields as well as recruiting fresh graduates and technicians, the British coal industry has now shown a scientific initiative which seems to be part of a fresh upsurge of activity throughout the world around this interesting material, coal. A measure of this development was afforded by the lively international conference organised last year at the Coal Research Establishment near Cheltenham. The present volume contains papers presented at this conference. It gives seven papers together with a short opening address by Mr. A. H. A. Wynn, a Scientific Member of the Board, and a more detailed closing address by Dr. J. Bronowski, Director of the Research Establishment.

Processes for the controlled oxidation of coal, although admitted to be of value in only a small number of cases, were discussed in the opening two papers. Briquetting and the carbonisation of briquettes formed the subject of the second session. In the third were studies of semicarbonisation in a fluidised bed and of the tars produced in fluidised carbonisation. Finally, M. J. L. Sabatier spoke on the industrial treatment of tar obtained by low-temperature carbonisation.

The emphasis on briquetting, carbonisation and tar treatment is understandable, but it is surprising that no coal preparation papers found a place under the sweeping title. There are other regrettable omissions. It may have been impossible to have included reports on the hot-sand carbonisation process or the binderless coal briquetting process in a crowded conference agenda. But they would certainly have added to the completeness of the book. The only remaining adverse criticism is that, in some degree, this book is back to front. A part of Dr. Bronowski's closing address was devoted to the problems and perspectives of coal research, including the economic issues. Extended and deepened, a paper on this theme would have suitably introduced both the conference and this book. It could have tied together a collection of bitty useful information; it might also have said what types of paper were called and why these in particular were chosen. The concept of valorisation of coal, so briefly introduced by Mr. Wynn, could have received more attention with some background on the tonnages involved and the difficulty of finding markets eventually for millions of tons of organic chemicals. Some of the lacunæ were noted by Bronowski; both these and the others may await the publication of a more integrated text.

Yet none of this is to decry the valuable accounts of investigations and processes which in some cases were then up to a scale of one ton an hour. The papers shed much light and also showed up some of the dark places. Of the latter, the most important appeared to be the difficulty of removing entrained solids from the gas stream after the fluidisation stage. This involves both the economics of the process and the avoidance of public nuisance.

With none of the glamour and public esteem attached to atomic energy research, and only a small fraction of its resources, this work has nevertheless reached an important middle stage. It may well need backing by a bigger effort on the fundamentals of coal chemistry and physics, but there is already useful material here for workers interested in large-scale coal processing.

I. BERKOVITCH

Thermodynamics

by Franklin P. Durham

Longmans, Green & Co. Ltd., London, 1957, 312 pp., 55s.

THIS is a text-book intended primarily for degree or diploma students reading engineering thermodynamics as a main subject. It covers most of the work required for a three-year course in the subject and includes chapters on "Heat Transfer" and "Gas Dynamics". It will be concluded that the treatment is necessarily brief and for the student making his first acquaintance with the subject some explanations will probably be inadequate. However, the presentation of the subject is good and technically it is quite sound. It is a pity that some topics which the average student finds difficult—for example, the concept of reversibility—and the full implications of the second law are not given more space.

The author uses his own system of notation, which differs slightly from the standard American system. This is less ambiguous, but is likely to lead to confusion when referring to different texts.

As is customary with American publications on engineering thermodynamics, the book does not deal with any practical aspects such as construction, performance or testing of heat engines. It will thus have value only when a reference to first principles is required.

There appear to be very few errors or omissions. The author's definition of nozzle efficiency (p. 206) is not usually accepted as such, and one or two of the temperature-entropy diagrams are misleading in that the slopes are wrong. The measurement of pressures below atmospheric does not appear to be mentioned. The student should find the book useful as a revision book, and one containing all the necessary information on the subject in a condensed form.

S. R. LAMOND

Economics of Atomic Energy

by Mary Goldring

Butterworths Scientific Publications, London, 1957, 179 pp., 15s.

THERE is always an air of magic in discussions on the costs of atomic power even when they are couched in sober terms and the results quoted in hundredths of a penny. The main reason for this lies in the item "credit for sale of plutonium". When discussing direct capital and other operating costs of atomic plants it is sometimes possible, politely, not to mention the research and development charges somehow secreted in budgets in which it is possible to spend £100 million without trace. But on reaching this item of plutonium credit one returns inevitably to the twilight land of military economics. In reading Miss Goldring's book, it is better to hurry on past the unfortunate opening stages—the foreword where her name is misspelt, the arch opening paragraphs, and the early chapter on the "popular science" of atomic energy. When she gets down to business, Miss Goldring provides a useful survey of this unique industry. On economic grounds, the British decision to give priorities to the reactors powered by natural uranium is endorsed. The main criticisms of our policy—and even these are rather muted—are connected with the relations between the Atomic Energy Authority and industry. At the moment, the Authority is responsible for research and for training personnel, while industry puts the results into commercial production. This book contains a plea to give industry the facilities to waste its own money in making expensive investigations of unprofitable designs, instead of pestering the Authority to waste the Government's money on its behalf. Yet, as the author herself admits, only a well-endowed public authority can afford the scale of installation and the potential scale of the inevitable failures that must occur in the nature of research and development. This is an interesting theme, but receives only a brief treatment. In essence, it forms part of the much greater subject of the relations between the publicly- and privately-owned undertakings in the mixed economy of Britain today.

I.B.

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Gilbert F. Kinney

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This book is written for those who work with plastics and for those who require background information for the proper utilization or specification of these materials. The various plastics are here described separately more or less in order of increasing complexity. A unified treatment, rather than a topical approach, permits the principles, concepts, and terminology to be established in the simpler cases, and utilized in treatment of the more complex materials.

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PLANT EQUIPMENT NEWS

New Manifold

A manifold suitable for applications where air pressure requires to be regulated is the new ¾-in. B.S.P. manifold valve, SF.1169, manufactured by Lang.

The unit, housed in a gunmetal body, incorporates a pressure-reducing valve operated by a large synthetic rubber diaphragm giving extreme sensitivity; stop valves on both high-pressure inlet and low-pressure outlets; a needle valve to give fine regulation of flow; a non-return valve for safety in the event of an air failure; and a 3-in. diameter pressure gauge graduated from zero to 160 psi. **Lang Pneumatic Ltd., Birmingham Road, Wolverhampton.**

BCE 2129 for further information

Constant Support Hangers

A prototype of a new range of constant support hangers for pipes or other equipment subject to thermal movement has been made by Vokes Genspring. The range will replace the H12 model and will be more compact and cheaper than the previous design. **Vokes Genspring Ltd., Guildford.**

BCE 2130 for further information

A New De-salting Plant

William Boby have completed the first assembly of a new design of plant for the de-salting of brackish water. The equipment has been developed by the company in association with the Chemical Research Laboratory of the D.S.I.R. and the Central Technical Institute at The Hague, Holland, and makes use of electrodialysis. The plant will be available in capacities of from 1000 to 10,000 gallons per hour, or more. The d.c. power required for operating can vary between 7 and 25 kWh. per 1000 gallons, according to the rate at which the water is desalted, but the a.c. power consumption is constant, and need not exceed 2 kWh. per 1000 gallons of water treated. It is assumed that the treatment of the Tobruk water will cost about 5s. per 1000 gallons of water produced, allowing 1s. 6d. to 2s. per 1000 gallons for the replacement of the membranes. The maximum economic output of the plant is 40 tons per day, based on the use of 200 membranes. The equipment, it is said, will work over almost any range of brackishness, but it is unlikely to be economic outside the range of 10,000 ppm total dissolved solids de-salted to 500 ppm TDS. **William Boby & Co. Ltd., Rickmansworth, Herts.**

BCE 2131 for further information

High-pressure Hot-water Valve

Features of the new MIL high-pressure hot-water valve include a packless gland and a method of adjusting the rate of flow through the valve which is not affected by closing and reopening the valve. The design of the passages through the valve and the inclined valve spindle ensure, it is said, unhindered flow and absence of crevices in which air can be trapped. The body and bonnet are of aluminium bronze, and the valve disc, spindle and packless gland of stainless steel. The alloy handwheel is shaped to protect the adjusting screw. The manufacturers have also commenced making a pressure-reducing valve for steam or gases in the sizes 1¼ in. and 1½ in. **Midland Industries Ltd., Heath Town Works, Wolverhampton.**

BCE 2132 for further information

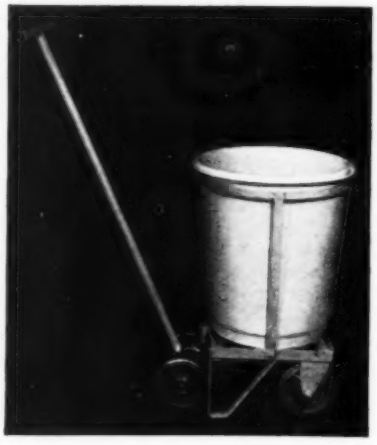
Air Filter

Air Control Installations are making the Rollotron air filtration unit in Great Britain under licence from the American Air Filter Co. The machine comprises a dry-plate electrostatic precipitator and a filter medium which is stored in a roll and, as required, is moved across the filtering area automatically. **Air Control Installations Ltd., Ruislip, Middlesex.**

BCE 2133 for further information

Movable Bin

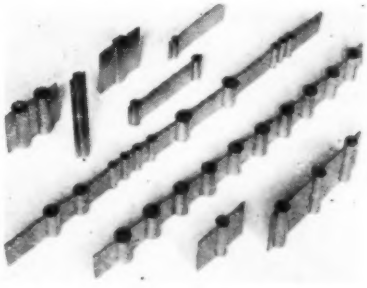
Charles Winn state that they can make their Truckbin available with a plastic bin suitable for the conveyance of chemicals within a factory. The bin can be of almost any shape and material. It is held in a metal framework, and, when not being moved, is supported firmly in this on two legs and two wheels. For moving, a two-wheeled bogie is quickly placed beneath the frame, so converting it into a small articulated truck. **Charles Winn & Co. Ltd., Granville Street, Birmingham, 1.**



BCE 2134 for further information

Tubes in Sheets

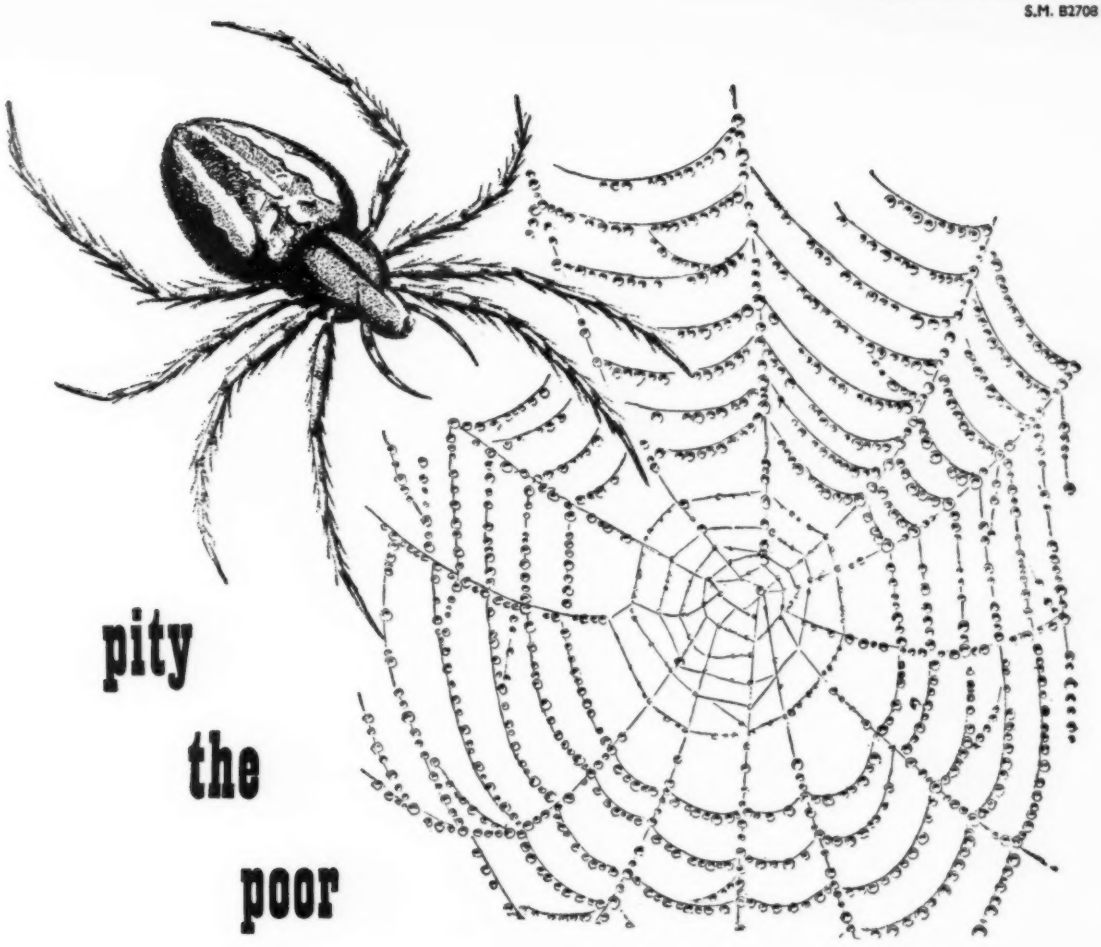
Tube-in-Strip, which provides a tube or a number of parallel tubes incorporated in a sheet or strip of metal, is the latest addition to the range of I.C.I. heat-transfer products. At present, it is made in copper and aluminium, but later it will be available in other non-ferrous metals. The range of tube diameters—at present limited to certain sizes between ¼ in. and 1 in.—will also be expanded as the need arises. Tube-in-Strip is made by the company's Metals Division on standard mill equipment. During the casting operation, rods of inert non-metallic material are incorporated in the rolling



slab. In the subsequent rolling, the rods break up into fine powder and elongate with the metal as it increases in length, finishing as a layer of fine powder about 0.001 in. thick within the strip, most of which is removed during inflation. The resulting gaps within the strip can then be inflated to provide tubes having a wall thickness half that of the strip. The material is cast in standard widths; before inflation the strip is slit and cut to length, to provide either a single tube or several tubes linked together by the connecting web of metal. The metal is delivered to the customer as sheet or coiled strip, so reducing packing and transport costs, particularly for thin materials where the risk of damage to inflated tubeways is considerable. The customer inflates the material when required. The product can be bent, formed or drawn before inflation or manipulated after inflation, as desired.

Conditions in which there will be special advantages in using Tube-in-Strip, it is said, include the following situations: (1) Where large radiant surfaces are needed, e.g., in water- or steam-heated radiators and solar energy absorbers. (2) Where conventional tube dia-

BCE 2075 for further information
S.M. B2708 D56



pity the poor spider

Condemned to combat the effects of water vapour every time the dew falls, the spider has had to adapt his way of life to the prevailing conditions. There is no need, however, for industrial production to suffer from the effects of atmospheric water vapour.

For all kinds of manufacturing plant, Birlec air conditioning equipment can be supplied to maintain specified low humidities between 50% R.H. to 1% R.H. Whether you manufacture chocolates or anti-biotics, food powders or fertilisers, Birlec direct dehumidifiers can circulate or supply dry air to conditioned spaces of almost any dimensions, ranging in volume from 500,000 cu. ft. down to 1 cu. ft.

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PLANT EQUIPMENT NEWS

meters would be chosen to give a required external surface area, but pressure drop considerations permit of smaller or fewer tubes being used. (3) Where tubes having a small thickness: diameter ratio are required, the cost of rolling Tube-in-Strip to thin gauge may be less than that of drawing a tube to a corresponding wall thickness. (4) In condensing of certain fluids, the efficiency of the lower tubes in the condensers is reduced by the thicker films of liquid deposited by the upper bank of tubes. By suitably orientating the fins of Tube-in-Strip, a controlled flow may be achieved, thus reducing interference effects between the tubes. **Imperial Chemical Industries Ltd., Gloucester House, Park Lane, London, W.1.**

BCE 2135 for further information

Shot-blast Machine

The Vacu-Blast Major is a development of the Vacu-Blast standard shot-blast machine. The generator-reclaimer section of the machine is now more sturdy and compact and a plug outlet is provided in the reclaimed section to enable quick removal of debris withdrawn

from the work surface. The dust collector is more compact; its cylindrical air filter unit comprises sock-type filters giving an increased cloth to air ratio, thereby improving the efficiency of the final air filtration. **Vacu-Blast Ltd., 291 Aberdeen Avenue, Slough.**

BCE 2136 for further information

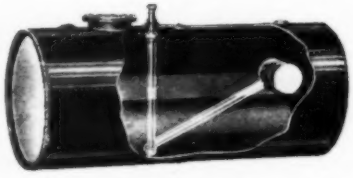
Liquid Relief Valves

A range of new liquid relief valves is being manufactured by Megator Pumps & Compressors. They are made of high-quality bronze with cadmium-plated carbon-steel valve springs. The company is also producing a new version of its mobile industrial pump, the pump set being mounted on a robust four-wheeled metal trolley, with welded tubular handle and bracing struts. The standard range covers capacities between 8 and 50 gallons a minute, but greater capacities are available to order. The set can be adapted to carry a length of flexible hose. **Megator Pumps & Compressors Ltd., 43 Berkeley Square, London, W.1.**

BCE 2137 for further information

Floating Decanter

The Bowser Fig. 280 floating suction, now being manufactured under licence by Liquid Systems, has been designed for drawing clear liquid from the surface of a storage tank. The device is constructed so that the float lowers as the liquid level falls and rises when the tank supply is replenished. The equipment consists of a



float, inlet flange, float clamp, swing elbows and nipples, and it is available in five standard pipe sizes. **Liquid Systems Ltd., Norwich Union House, Wellesley Road, Croydon.**

BCE 2138 for further information

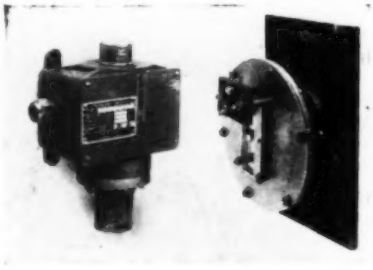
Welded Steel Tubes

Talbot Stead have commenced the production of stainless-steel welded tubes, and the first runs will be made in Metior 1 (18/8) quality. A further development announced by the company is the supply of drawn welded tubing which is made by certain draw-bench passes after the welded tubes have been produced from strip. By this means intermediate sizes of tubing can be manufactured, and it is expected that the standards required by the brewing, dairy and food trades will be met after the tubes have been polished internally and externally. Low-pressure equipment under corrosive conditions is also expected to utilise stainless-steel tubing of these qualities, and the company expect to be able to offer their Metior 2 (18/8/Ti) and Metior 6 (18/8/Mo) qualities in the very near future. **Talbot Stead Tube Co. Ltd., Green Lane, Walsall.**

BCE 2139 for further information

Pressure Switches

Londex are producing two new pressure switches. The new POS switch operates on extremely low pressures, and can be used for a variety of applications. If coupled to a rubber tube it can be used as a limit switch, for vehicle



counting, as an alarm device to give warning of persons entering or leaving premises, or for door-opening control. The new PS/P switch is designed for operation on oil hydraulic systems. The switch is generally similar to the company's other standard switches, but it utilises a piston as the pressure-sensitive part instead of bellows. **Londex Ltd., 207 Anerley Road, London, S.E.20.**

BCE 2140 for further information

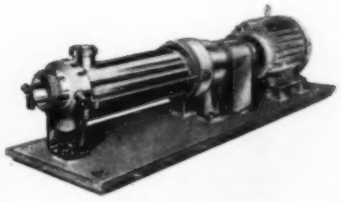
Polishing Solutions

Albright & Wilson have added two products to their range of Phosbrite chemical polishing solutions. Available initially on an experimental basis, they are Phosbrite 183, for treating basis and cartridge brass, and Phosbrite 184, for gilding metals. The tanks in which the preparations are used can be made of stainless steel, p.v.c.-lined mild steel, chemical stoneware or glass, and solutions are operated at optimum temperatures of respectively 65°C and 60°C. Fume-extraction equipment is essential and may be made of p.v.c. **Albright & Wilson (Manufacturing) Ltd., 1 Knightsbridge Green, London, S.W.1.**

BCE 2141 for further information

Hygienic Pump

A new hygienic pump, the Mono Kwikleen K63, is being made by the Industrial Pump Division of Mono Pumps. Stripping for sterilisation is carried out by two simple operations with the aid of a combined screwdriver and tommy bar. All internal surfaces of the pump are polished stainless steel and the stator is of non-contaminating composition. The pump is suitable for handling milk and other fluid edible products. It



is self-priming up to 25 ft and can be used for vacuum extraction duties. The makers claim that the consistent rate of discharge makes it very suitable for high-temperature short-time processing. The pump now available has a capacity up to 3000 gallons an hour with a maximum pressure of 30 psi, but a range of these pumps is expected to be made. **The Mono Group of Companies, 1 Sekforde Street, London, E.C.1.**

BCE 2142 for further information

Coolant Centrifuge

The Turbomatic centrifuge has been developed by Alfa-Laval for the clarification of grinding coolants. The company claim that the machine gives an efficiency of 99.98% continuously at throughput rates of up to 2200 gallons an hour, of either oil or aqueous coolant. The machine has an inclined centrifugal

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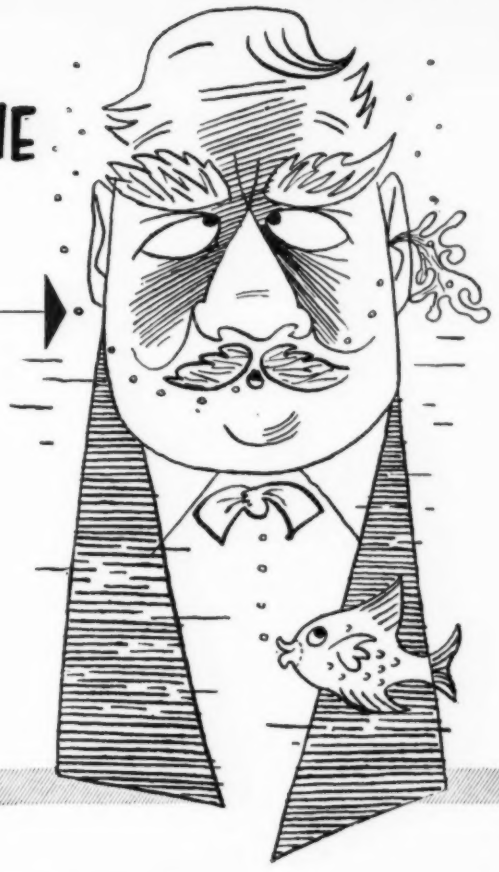

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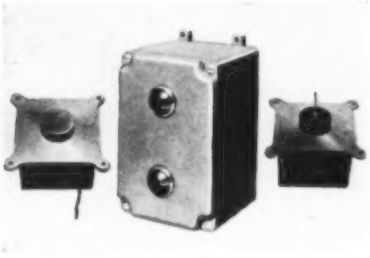
PLANT EQUIPMENT NEWS

bowl running at 1450 rpm, and it is fitted with a disc pack to give high-efficiency separation. The extracted sludge builds up on the bowl wall, from which it is thrown down into the sludge trough (which forms the base of the unit) when required. The ejection is achieved by the rapid braking of the bowl through the use of a current-reversing switch. **Alfa-Laval Co. Ltd., Great West Road, Brentford, Middlesex.**

BCE 2143 for further information

Level Controller



Great sensitivity and stability are claimed for the new Goring Kerr level controller. A novel feature which the makers also claim is that the instrument is self-compensating for substantial deposits on the probes. Cable up to 300 ft in length may be supplied with the instrument for linking the probe or probes to the indicator unit. **Goring Kerr Ltd., Station Road, Gerrards Cross, Bucks.**

BCE 2144 for further information

Non-inflammable Conveyor Belt

A new non-inflammable conveyor belt, Rilflex, is being manufactured by Rubber Improvement, and has just been approved by the National Coal Board. The production of the belt is the outcome of considerable development work by the makers in conjunction with I.C.I. The belt is composed of three plies of Terylene reinforced-fabric coated with p.v.c. It is half the thickness of a six-ply cotton belt, is lighter and more flexible than the cotton product and is, it is claimed, just as strong and non-inflammable. **Rubber Improvement Ltd., Wellingborough.**

BCE 2145 for further information

New Grades of Kieselguhr

Five new grades of calcined German kieselguhr (diatomaceous earth) are now available as filter aids from Charles H. Windschuegl, sole suppliers in the United Kingdom. The grades have been designated 70.S.New, 80.S.New, 80.S.B., 80.S.Standard and 80.Super, and replace former grades. Bulk volume has been increased by as much as 16% and the life cycle has been extended. One large brewery has reported that yield per dosage has increased to five barrels, as against three and a half with the previous grades. The improvements have been made possible by the exploitation of fresh deposits of crude gur with new quarrying techniques and the development of artificial methods of drying which will not damage the intricate structure of the diatoms. The producers are therefore no longer dependent on favourable weather conditions for the operation of the natural "Meiler" burning process. New mills, sand sifters and a close control system at every stage of production have also been introduced. **Charles H. Windschuegl Ltd., 1 Leadenhall Street, London, E.C.3.**

BCE 2146 for further information

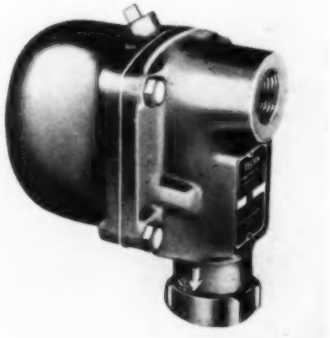
New Ion-exchange Resins

Permutit are now producing on a quantity basis a range of cation and anion exchange resins of varying degrees of cross-linking and with different particle sizes for chromatographic separation and analytical purposes. The resins are based on the company's Zeo-Karb 225 and De-Acidite FF ion-exchange resins. **The Permutit Co. Ltd., Gunnersbury Avenue, London, W.4.**

BCE 2147 for further information

Float Thermostatic Steam-trap

The new Velan steam-trap is said to be of unique design. It is very small and compact and is supplied complete with an integral strainer, air vent and check valve. The entire mechanism, including the float, is made of stainless steel. The trap will discharge condensate at steam temperature, and does not require a temperature drop for its operation. Incorporated on the float lever mechanism is the standard Velan bimetallic element. When condensate at steam temperature enters the trap, the element pulls the valve tight on to its seat; the float chamber then starts to fill, and the float rises, cancelling out the pull of the bimetal



element, due to the position of the fulcrum. The valve is lifted off its seat, and the condensate is discharged. Water hammer, it is said, has no damaging effects on either the element or the float. The valve, being on the downstream side of the seat, acts as a relief valve, preventing excessive pressure build-up in the trap body. The trap is available with ½-in. and ¾-in. B.S.P.T. connections. Pressure ranges are 0-60 psi and 0-120 psi, and capacities 1700 lb./hr at 60 psi and 2250 lb./hr at 120 psi. **British Steam Specialities Ltd., Fleet Street, Leicester.**

BCE 2148 for further information

Diaphragm Pumps

After a long period of field trials and development work, Wilkinson Rubber Linatex can now offer a range of Linatex diaphragm pumps varying in drive and linings to suit a wide range of purposes. A feature of the pumps is the vertical mounting of the motors. The motors may be of a variety of types, including standard squirrel cage or flameproof, and the linings of, for example, Linatex for abrasive slurries or, for corrosive

materials, butyl, nitrile or Hypalon. **Wilkinson Rubber Linatex Ltd., Camberley, Surrey.**

BCE 2149 for further information

Smoke Indicator

The new Radiovisor smoke-density indicator, RV.2, registers on a meter calibrated in percentage obscuration, and it complies with B.S.S. 1957. The light beam is effective up to a maximum distance of 35 ft; the projector and receiver are mounted in robust cast-alloy housings of similar design and are dustproof. The optical system in both units is protected from the flue gases by plate-glass windows, and purging air orifices allow clean air to pass over the windows. A unique feature in the projector is the incorporation of a spy hole through which the receiver can be seen across the flue, for helping alignment and focusing. Equipment type SA.56 provides an alarm only. **Radiovisor Parent Ltd., Stanhope Works, High Path, London, S.W.19.**

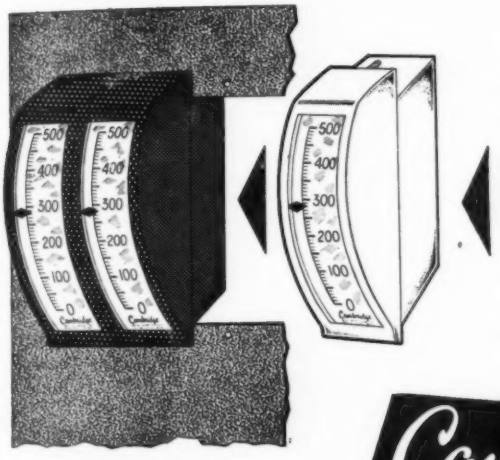
BCE 2150 for further information

Wet Reagent Feeder

The K.B. wet reagent feeder is a disc-type machine which is claimed to be very simple to operate and cheap to install and maintain. A typical four-bladed model consists of a welded steel U-shaped 4½-gallon tank which is welded into an external steel tank. A ¾-in. mild-steel hollow shaft, supported on two oilite bearings, passes through the tank and carries four 12-in. diameter steel discs. The steel blades gather reagent and deliver it to two horizontal steel wipers which are fitted radially to each

BCE 2077 for further information

No limit to the number . . .



Only the size of your panel limits the number of **Cambridge New Unit Type vertical scale indicators** which can be mounted side by side. Every inch of panel space can be used. Units can be added, at any time, without inconvenience. If necessary, a unit can be replaced rapidly by a spare. The indicators are available for temperatures up to 1000° F., for draught measurements, and for pressures up to 2500 lb. per square inch.

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3 UNITY STREET, BRISTOL, 1 — Telephone : Bristol 26996
6 BRITANNIA HOUSE, WELLINGTON STREET, LEEDS, 1 — Telephone : Leeds 23537

BCE 2078 for further information

PLANT EQUIPMENT NEWS

blade. The liquid removed by the wipers falls by a trough to a receiving box and is discharged through ½-in. diameter drain

plugs. The reagent is agitated by the rotation of the discs and a constant level is maintained by an iron ball-valve. The position of the wipers is adjustable to give any blade setting between a fraction of an inch and the full length of 5 in. The unit is powered by a 0.125-hp, 220-volt, 50-cycle, single-phase motor. Four types of unit are available. **Knapp & Bates Ltd., Africa House, Kingsway, London, W.C.2.**

BCE 2151 for further information

Tube Cleaners

Production of Lagonda tube-cleaning equipment, including all types of cutter head and boring tool, has commenced in Britain. This is the outcome of recent negotiations between the Elliott Co., a division of the Carrier Corp., of Springfield, Ohio, U.S.A., manufacturers of the Lagonda equipment, and the Consolidated Pneumatic Tool Co. Ltd., British manufacturers of air compressors and portable power tools. The initial range now in production at the Scottish factories of Consolidated Pneumatic comprises all the sizes in general demand, from the Model 600 series for heat exchangers and condensers to the 1100 and 1300 series of motors for both straight and curved tubes in 2¼-in. diameters upwards. Initial supplies of the British-made Lagonda equipment are expected to be available over the coming months, and regular production of the complete range will be in hand before the end of 1957. **Consolidated Pneumatic Tool Co. Ltd., 232 Dawes Road, London, S.W.6.**

BCE 2152 for further information

Other Items of Interest

A valve having a closure stop designed to prevent overclosure and to act as a simple visual valve position indicator is being made available by Saunders Valves. It is applicable to most of the company's valves, including some plastic models. **Saunders Valve Co. Ltd., Cwmbran, Mon.**

BCE 2153 for further information

The Barnet Oxytester has been designed for testing pressure gauges for oxygen, air, etc., without filling them with oil. It may be used with any suitable dead-weight tester, and provides a baffle between the oil in the tester and the liquid permissible in the pressure gauge. **Barnet Instruments Ltd., Bath Place, Barnet, Herts.**

BCE 2154 for further information

A pickling solution incorporated in a thixotropic jelly is available from Walterisation. The preparation enables the pickling to be carried out *in situ*. The solution, in effect, is applied directly to the surface and is held, by subsequent gelling, in contact with the scale without running off. The product is known as Waltergel. **The Walterisation Co. Ltd., Purley Way, Croydon.**

BCE 2155 for further information

A new metal-spraying pistol, Mk. 33, having a magnetic control, is being made by **Metallisation Ltd., Barclays Bank Chambers, Dudley.**

BCE 2156 for further information

Camron hydrostatic tank-gauges, type OM, are suitable for rectangular tanks up to 6 ft in height and cylindrical tanks of up to a diameter of 6 ft. Designed primarily for indicating the content of oil tanks, they contain no moving parts and are calibrated before delivery. **Camron Engineering Co. Ltd., Havant, Hants.**

BCE 2157 for further information

Fordhams have introduced the Acquasave ball-valve made from high-density polythene, and they claim that it is the first valve to be moulded from plastic material. The nozzle moulding is available with the orifice sizes ⅛ in., $\frac{7}{16}$ in. and ¼ in. **Fordham Pressings Ltd., Dudley Road, Wolverhampton.**

BCE 2158 for further information

Alite Machines have developed a machine for end-coding cylindrical containers such as aluminium boxes and flat-bottomed tubes. Its speed is 60 operations a minute. **Alite Machines Ltd., Pixmore Avenue, Letchworth, Herts.**

BCE 2159 for further information

Courtburn Positioners announce a new portable rotator for manual or automatic welding of cylindrical vessels. The FB 40, as it is known, has a maximum load capacity of 2 tons, and will accommodate all diameters up to 9 ft and lengths from 12 in. to 12 ft. **Courtburn Positioners Ltd., Kempston Hardwick, Bedford.**

BCE 2160 for further information

A quick-release flameproof overall is being made by R.F.D. for protection against the risk of flash in processes involving the use of sodium liquid and solid. **R.D.F. Co. Ltd., Godalming, Surrey.**

BCE 2161 for further information

Farrow & Jackson are now marketing a new hand-operated hydraulic elevating trolley. The standard model has a top area of 33 in. by 21 in. It is 29 in. high unextended, and is capable of lifting loads of up to 8 cwt. to the full extended height of 48 in. in 35 seconds. **Farrow & Jackson Ltd., 41 Prescot Street, London, E.1.**

BCE 2162 for further information

After four years of applied research and trials, United Coke & Chemicals, a subsidiary of United Steel, have begun full-scale production of their new Orkot reinforced synthetic resin bearings for steel-rolling mills at their Orgreave works, near Rotherham. **United Coke & Chemicals Co. Ltd., 17 Westbourne Road, Sheffield, 10.**

BCE 2163 for further information

New Publications

Air Control Installations Ltd. have forwarded us a selection of their recently published literature. These are as follows: G.5703, which covers the range of equipment manufactured by the company; F.5701, which is a more specialised publication dealing with the company's fans; E.5702 describes the Dusman which, the company states, provides complete collection for dangerous particles evolved in grinding, finishing and polishing operations; B.5704 details an automatic renewable media air filter (Roll-o-matic); FB.5707 covers small blowers, cooling fans and dust filters which will be of particular interest to the electronics engineer; B.5708 describes a multi-pack air filter; E.5709 details the Amer-Clone dry centrifugal dust collector, which the company claims is new in principle and revolutionary in design; E.5710 describes the Amer-jet high-efficiency dry-type collector; E.5711 gives details of a precipitator (electro-mist) designed for oil mist and fume collection; B.5712 illustrates and details the Cycoil type P, claimed to be a new-design low-resistance-type oil bath and air cleaner; and Publication No. 6543, which covers the company's Roto-clone, details foundry dust control data. Copies from **Air Control Installations Ltd., Ruislip, Middlesex.**

BCE 2164 for further information

Publication No. 7009 (which supersedes No. 7007), dealing with electrostatic precipitation, has just been announced by **Sturtevant Engineering Co. Ltd., Southern House, Cannon Street, London, E.C.4.**

BCE 2165 for further information

Two Technical Service bulletins (No. 310c, which describes the manufacture of Epophen plastic tools using Epophen epoxide resins, and No. 169, describing the Epophen epoxide laminating resins), have just been issued by **Leicester, Lovell & Co. Ltd., North Baddesley, Southampton.**

BCE 2166 for further information

Radiovisor have produced an attractive leaflet on their flame-failure protection equipment for oil, gas and pulverised-fuel burners. **Radiovisor Parent Ltd., Stanhope Works, High Path, London, S.W.19.**

BCE 2167 for further information

A new series of valve material leaflets has just been published by **Langley Alloys Ltd., Langley, Slough, Bucks.**

BCE 2168 for further information

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Month's News in Brief

United Steel Structural Co. Ltd., a subsidiary of The United Steel Companies Ltd., are to fabricate and erect the structural steelwork for the new £60 million nuclear power station at Hinkley Point, Somerset. Working in collaboration with Taylor Woodrow Construction Ltd., the civil engineering contractors for the project, United Steel Structural will supply between 8000 and 9000 tons of steelwork for the reactor building, turbine house, workshops and ancillary buildings. Erection is expected to begin towards the end of next year and the power station will be completed by the end of 1962. It will be the largest of its kind in the world and the first to generate electricity at a cost comparable to conventional power stations.

The Textile Institute have announced a new scholarship—the Frank Wright Scholarship—which will enable the recipient to further study in the U.S.A., at either the Textile Research Institute, Princeton (in association with the University of Princeton), or at the Massachusetts Institute of Technology. Candidates must have been born in the United Kingdom and must possess a university degree of sufficient standing to permit of eligibility for attendance at one of the two American institutions. The scholarship holder will be expected to give an undertaking to return to the U.K. at the conclusion of his course and to work here for a period of at least five years. Application forms may be obtained from the General Secretary of The Textile Institute and must be returned not later than October 31, 1957.

The Australian Minister for Trade, Mr. McEwen, believes that Australia's secondary industries have reached such an advanced stage that they are in a position to export technical know-how, as well as actual products. Mr. McEwen made this statement recently while opening a factory in Melbourne, which will manufacture water purification equipment, partly for export to South-east Asia. He said that there was a ready demand in overseas countries for Australian technicians, but Australia itself needed the services of many more of them. However, with planning programmes now in hand, Australia should, in the future, be able to export technicians as freely as she now exported goods.

Servomex Controls Ltd. have announced several important changes in trading methods, to become effective on January 1, 1958. These are: (1) a new world-wide price list will take the place of the present home and export list; (2) new contracts with overseas agents will give greatly increased incentives to sell Servomex designs and hardware; and (3) agency agreements in the U.K. will cease. Servomex state that these are the first moves to a more rational trading system, made necessary by the trend towards a true European market.

Royal Dutch Petroleum Co. and the "Shell" Transport & Trading Co. Ltd. have confirmed that for some time they have been actively exploring the possibilities of raising new capital by means of share issues to be made early in 1958. These issues would be for the purpose of meeting the needs of the Royal Dutch/Shell Group of companies for additional funds required for future capital expenditure. It is expected that the Royal Dutch offering would be in the form of a "rights" issue to shareholders, and would be for an amount of between Fl. 800 million and Fl. 1000 million (equivalent to £75 to £94 million). The price would not be related to nominal value, but would be governed by market conditions prevailing at the time of the issue. The "Shell" Transport & Trading Co. Ltd. would make a similar offering to shareholders for an amount of between £40 million and £55 million, subject to approval by the Capital Issues Committee.

The Scientific Instrument Manufacturers' Association is holding its sixth annual convention at Eastbourne from October 24 to 27, 1957. Entitled "Enterprise 1958", the event is mainly concerned with the commercial side of the industry and will consider the outward-looking topics of meeting the challenges of the future, especially that of the European free trade area.

Dr. H. J. Bhabha, chairman of India's Atomic Energy Commission has said in an interview that the production of a million kw. of nuclear fuel energy between 1962 and 1965 was a "definitely feasible target" for India.

The demand for Terylene for a wide range of clothing, personal and industrial uses continues to increase, and an extension of plant capacity from 22 million lb. to 30 million lb. a year is under construction. Plans are well advanced in the Fibres Division of I.C.I. for a further increase of capacity of 20 million lb. a year of Terylene fibre, involving the building of an entirely new plant at Wilton which is expected to cost, with supporting plants, approximately £20 million.

Pilkington Bros. Ltd., of St. Helens, Lancashire, have announced with regret that Ashdowns Ltd., of St. Helens, their subsidiary manufacturing plastics, would be closed down by December 31, after outstanding trade commitments have been met. The activities of Mendip (Chemical Engineering) Ltd., an Ashford, Middlesex, concern engaged in the development of fibreglass reinforced plastics for the chemical industry, acquired by the Pilkington Group in May, 1957, will continue.

Chemical Construction (Great Britain) Ltd. announce that they have received an additional contract from British Titan Products Co. Ltd. for a sulphur-burning contact sulphuric-acid plant.

A further order for glass pipe-line and fittings for the Polymer Corporation of Sarnia from the Meade Laboratories at Richmond Hill, Ontario, is announced by Q.V.F. This is the second such order; the earlier order, valued at £10,000, was the largest consignment of glass pipe-line ever shipped from this country.

A new 20-in. diameter pipe-line is carrying natural gas from the La Paz oilfield, in the Maracaibo district of the state of Zulia, to the Cardon oil refinery on the Paraguana peninsula, Venezuela. Costing £9 million and built in a year, the line is 180 miles long and has a nominal capacity of 100 million cu. ft a day.

The next British Plastics Exhibition and Convention is to be held at Olympia, London, from June 17 to 27, 1959. The exhibition is to be renamed the International Plastics Exhibition and Convention.

Polypenco Ltd., plastics manufacturers, announce that they have recently opened an office and factory in Tewin Road, Welwyn Garden City.

The address of the Accumulator Makers' Association is now 77 Bedford Court Mansions, Bedford Avenue, London, W.C.1. Tel. MUSeum 8976.

Sir W. H. Bailey & Co. Ltd. recently celebrated their 125th anniversary by organising a technical Press visit to their works and publishing a new illustrated reference book listing the wide range of valves and boiler accessories manufactured by the company.

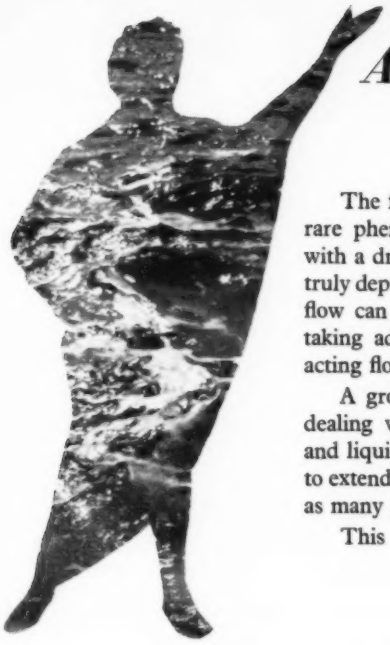
An explosion at E. R. Squibb & Sons' pharmaceutical factory at Speke, Liverpool, killed one man injured five others.

The United Kingdom Atomic Energy Establishment at Harwell has brought into operation Zeta, an apparatus for the experimental production of thermonuclear power. Designed to reach temperatures in excess of 1 million °C, it has been in operation since August 15 this year.

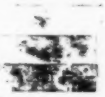
At its Council meeting held at Southport on September 25, the Federation of British Rubber and Allied Manufacturers accepted into associate membership some seventeen companies manufacturing machinery, chemicals or components for the British rubber industry in the United Kingdom and the Commonwealth.

Quickfit & Quartz Ltd., manufacturers of interchangeable laboratory glassware, of Stone (Staffs.) are turning their attention to potential markets in the U.S.S.R. and China. This was stated at the annual general meeting of the Triplex group of companies in London recently by Sir Graham Cunningham, chairman and managing director. Sir Graham said that, although Russia and China buy through their Government departments, the demand for Q. & Q. scientific laboratory apparatus came from the scientists and workers in the laboratories of their chemical factories.

Ten young men from Commonwealth countries, winners of Shell scholarships valued at £750 each, will begin post-graduate courses in both science and arts at British universities this autumn. As an international concern, operating in almost every country in the world, Shell offers these scholarships to young men of outstanding promise in order to encourage the development of a truly international



A Tide in the Affairs of Men . . .



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outlook among those who, whether in industrial, commercial or cultural spheres, can be expected to have an influence far outside their chosen profession.

Brighton Industries Ltd. (one of the Ayling Industries Group companies) has moved its headquarters from Portslade, near Brighton, to a new factory at Burgess Hill, Sussex. To avoid any confusion that might arise over the retention of the word Brighton in its title, and because the registered name "Bribond" is widely known and more correctly covers future development, the company has changed its name. It is now known as Bribond Ltd.

Examples of the work of I.C.I. Metals Division on the development of "canning" materials in aluminium and magnesium alloys for nuclear reactors will be given on the Division's stand at the forthcoming Corrosion Exhibition. The Division will also have something to say about its development of zirconium and niobium for use in reactors still in the course of construction. I.C.I.'s display will consist of a number of sections each designed to show, by the use of specimens and photographs, the metals which have been developed to withstand corrosive and/or erosive action in various industries.

An order for £54,000 worth of plastics machinery and high pressure fittings has been obtained by the Burtonwood Engineering Co. Ltd., of Warrington, Lancashire, from the Royal Dutch State Mines. The whole of this equipment is for the manufacture of Polythene—a new development for the Royal Dutch Mines. Another recent order obtained by the company is for £28,000 worth of plastics equipment from France. These goods are for a new Normandy plant of the Ethylene Plastique organisation.

B.K.L. Alloys Ltd., of Birmingham, have opened a London office. The new offices are at 16 Berkeley Street, W.1 (Tel.: MAYfair 2779), and are under the management of Mr. C. M. Powell.

The name of Costain-John Brown Ltd., a wholly-owned subsidiary of John Brown & Co. Ltd., has now been changed to Constructors John Brown Ltd.

Forthcoming Events

Home

October 21. *2nd Symposium on Coal Preparation, organised by the Coal Preparation Plant Association:* At The University, Leeds, until October 25.

November 5. *National Industrial Fuel Efficiency Conference, organised by The Combustion Engineering Association:* At Harrogate, until November 6.

November 6. *Conference on the Application of Research for Better Methods of Management, organised by the British Institute of Management:* At Bournemouth, until November 8.

Overseas

October 18. *International Electric and Atomic Show, organised by the Danish Electric Development Association:* At Copenhagen, Denmark, until October 27.

October 28. *4th Annual Conference on Management, Economics and Technology for the Atomic Industry, organised by the Atomic Industrial Forum:* At New York, U.S.A., until October 30.

October 30. *Rocky Mountain Minerals Conference, organised by the American Institute of Mining, Metallurgical and Petroleum Engineers:* At Denver, Colorado, until November 1.

November 2. *2nd World Metallurgical Congress, organised by the American Society for Metals:* At Chicago, Illinois, until November 8.

November 2. *International Congress and Exhibition of Measuring Instruments and Automation:* At Düsseldorf, Germany, until November 10.

November 3. *2nd International Conference on Non-destructive Testing, in conjunction with 2nd World Metallurgical Congress:* At Chicago, Illinois, until November 8.

November 3. *4th Pan American Pharmaceutical and Biochemical Congress, organised by the American Pharmaceutical Association:* At Washington, U.S.A., until November 9.

People in the News

At a recent meeting of the board of directors, **Mr. H. Driver**, M.B.E., T.D., was appointed a director of Monsanto Chemicals Ltd. Mr. Driver, who had previously been appointed an alternate director on March 25, 1957, will continue in his office as secretary of the company and head of the legal department. As an executive director, Mr. Driver is also responsible for insurance, Monsanto House administration and, in conjunction with the chairman, new financing.

Under a reorganisation announced recently, Cleveland Motors Ltd., of Redcar, has become part of the international group of companies controlled by Neptune Meter Co. of New York, U.S.A. **Mr. Danti E. Broggi**, president and chief executive officer of Neptune, is chairman of the British Company, whilst the new managing director is **Mr. A. Hargreaves**, formerly technical director of Cleveland Meters. He succeeds **Mr. Gerald W. Fleming** who becomes vice-chairman. The board of directors also includes **Mr. Edward Meeson** as technical director, and who has been associated with the company from its inception, and **Mr. David Summers**, of Bankers Trust Co., London.

Mr. G. M. Harvey has been appointed managing director of British Oxygen Wimpey Ltd. He relinquishes his appointment on the company's board as design manager.

Mr. V. Thomas, general sales manager

A. Hargreaves

Comdr. M. B. St. John.

of Fielden Electronics Ltd., announces four new appointments to home sales staff. Appointed manager of the new industrial electronics division is **Mr. A. R. Blanchard.** Two new technical representatives, **Mr. F. G. Totty** and **Mr. R. Shaw**, have been appointed, and they will be responsible for Yorkshire and East Lancashire respectively. Finally, **Mr. K. Adams** has joined Fieldens to take over statistics and market research.

Comdr. Michael B. St. John, D.S.C., R.N. (Ret.), has been appointed managing director of Liquid Systems Ltd. who, with Rubery Owen & Co. Ltd., contract to manufacture the Bowser range of industrial equipment in this country.

Chemstrand Ltd. has announced the appointment of **Mr. John Cannon** as advertising and public relations manager.

Following the appointment of **Sir Christopher Hinton**, K.B.E., F.R.S., as chairman of the Central Electricity Generating Board, **Sir Leonard Owen**, C.B.E., at present director of engineering and deputy to the managing director of the Industrial Group of the A.E.A., has been appointed managing director of the Industrial Group.

Sir Alexander Fleck, chairman of Imperial Chemical Industries, Ltd., has been elected president of the British Association for 1958.

After nearly 52 years' service with Price's (Bromborough) Ltd., **Mr. Robert Eaton**, the manager of their Fatty Acid Department, has retired.

Sir Miles Thomas, chairman of Monsanto Ltd., is to join the British Productivity Council. He has been nominated by the Federation of British Industries to succeed **Sir Ewart Smith**, former B.P.C. chairman, who has decided to resign after serving on the Council since its inception in 1952.

Gas Council scholarships awarded this year are as follows:

Arthur Richmond (University of Oxford, Department of Inorganic and Physical Chemistry): The mechanism of gaseous oxidation processes. **Kenneth J. Reid** (University of Cambridge, Department of Chemical Engineering): Chemical engineering fundamentals. **Philip Hawtin** (University College, University of London, Department of Chemical Engineering): Heat transfer with a special interest in heat transfer to gases. **David Wilson** (University of Birmingham, Department of Chemical Engineering): Gas absorption. **John N. Sherwood** (University of Glasgow, Department of Chemistry): Diffusion studies in molecular crystals.

Dr. L. G. Groves has been appointed managing director of Davy British Oxygen Ltd., and has relinquished his appointment on the board of British Oxygen Wimpey Ltd.

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MONSANTO CHEMICALS LIMITED have vacancies for Chemical Engineers in their Chemical Engineering Research Department. Applicants should possess an honours degree or equivalent qualification in chemical engineering. Previous industrial experience, although desirable for some of the posts, is not essential. Work covers the development of new processes and equipment entailing bench scale and pilot scale design work, together with the operation on pilot units. Salaries fully commensurate with qualifications and experience will be paid, and a non-contributory pension scheme is in operation. Full details of age, education, qualifications and experience should be sent to the Chief Personnel Officer, Monsanto Chemicals Limited, Monsanto House, 10-18 Victoria Street, London, S.W.1.

CHEMICAL ENGINEERS FOR REFINERY PROCESS ENGINEERING

The Bahrein Petroleum Company Limited have openings in their Research and Development Department for Graduate Chemical Engineers interested in Refinery technical service work concerned with the evaluation of process performance, process and product quality control and technical planning for forward operations.

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A CHEMICAL ENGINEER is required to take full charge of Research Department for the design, development and commissioning of new chemical processes and plants allied to the Gas and Chemical Industries. Applicants should preferably hold a qualification in Chemical or Gas Engineering, together with several years practical experience. The position offers exceptional scope for initiative and responsibility, is permanent and pensionable, and the salary would be commensurate. Applications, which will be treated in the strictest confidence, should state age, qualifications, experience and an indication of salary scale, and be addressed to the Managing Director, Robert Dempster & Sons Ltd., Rose Mount Iron Works, Elland, Yorkshire.

MANCHESTER Oil Refinery Ltd., have vacancies in their Production and Development departments for Chemical Engineers, Chemists or Mechanical Engineers. The Company produces a wide range of lubricating oils, white oils and sulphonates and some interesting new developments are in progress. Non-contributory Staff Assurance Scheme in operation. Canteen facilities, etc. Write in first instance to Personnel Officer, Manchester Oil Refinery Ltd., Twining Road, Trafford Park, Manchester, 17.

PROJECT ENGINEER with sound knowledge of applied thermodynamics required for young progressive company engaged in low temperature processes allied to the chemical and steel industry. A knowledge of gas separation desirable but not essential. Salary in accordance with age and experience, five-day working week and pension scheme. Apply to the Chief Engineer, Air Products (Great Britain) Ltd., 9 Upper Belgrave Street, S.W.1.

SENIOR ASSISTANT in Sales Office required for Birmingham Tube Fittings Manufacturer supplying the Oil and Chemical Industry. Duties include preparation of Quotations. Order Confirmations, Telephone Enquiries, and correspondence. Pensionable, progressive position in expanding organisation. Boz B.C.E. 34.

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